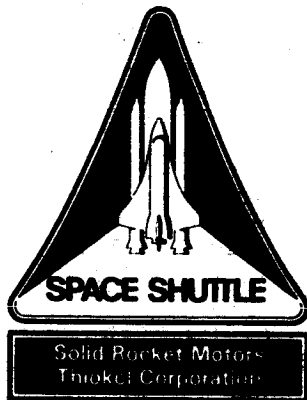


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Flight Motor Set 360H005 (STS-28R) Final Report

**Volume I
(System Overview)**

October 1989

Prepared for:

**National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812**

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***Thiokol* CORPORATION
SPACE OPERATIONS**

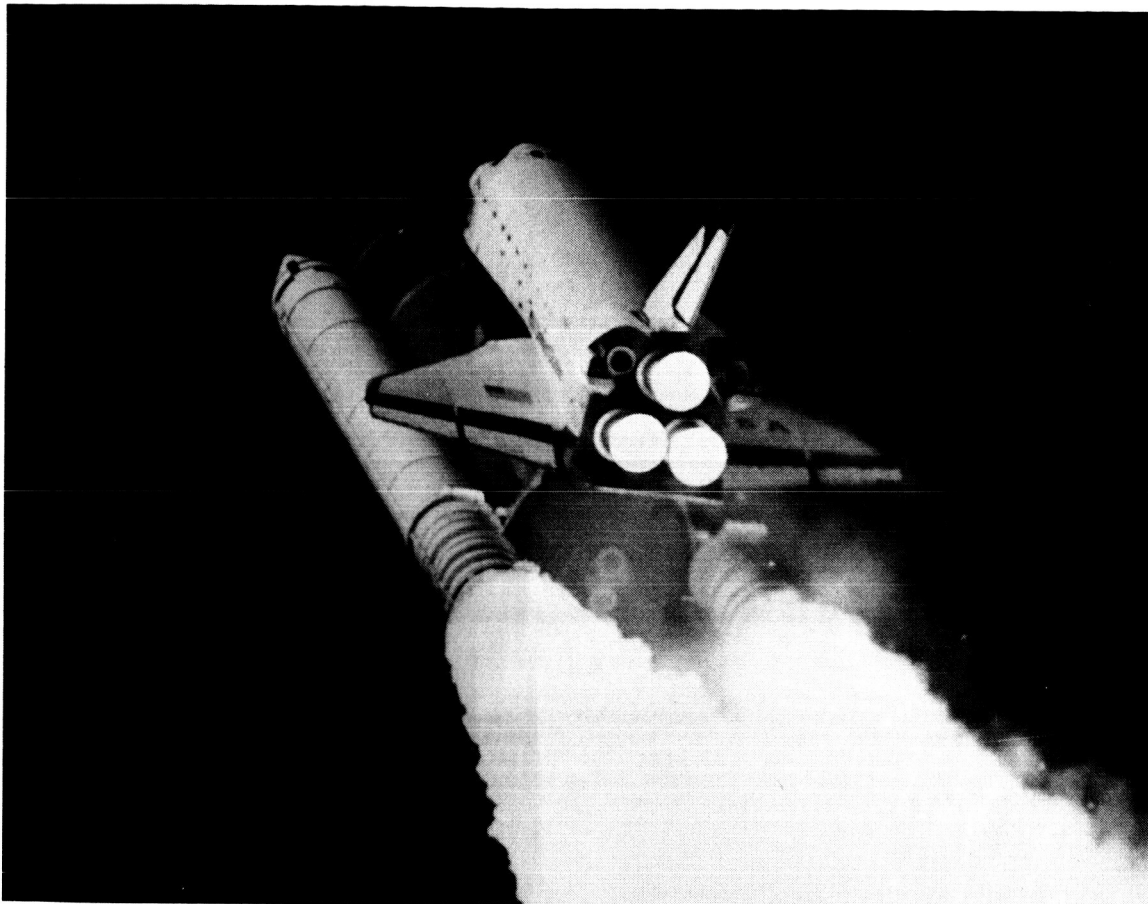
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Assisted by Thiokol flight motor set 360H005, the orbiter Columbia returns to flight on 8 August 1989 after a down period of over 3 1/2 years. Both the orbiter and the redesigned solid rocket motors performed in a near- flawless manner throughout their respective mission stages.

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ABSTRACT

Flight motor set 360H005 was launched at 8:37 a.m. EDT on 8 August 1989 as part of NASA space shuttle mission STS-28R. As with all previous redesigned solid rocket motor launches, overall motor performance was excellent.

As a result of elimination of developmental flight instrumentation, complete verification of all ballistic contract end item specification parameters was not possible. However, the low sample rate data that were available showed exceptional propulsion performance. All ballistic and mass property parameters closely matched predicted values and were well within required contract end item specification levels that could be assessed. No strain, vibration, or aft skirt heating environments could be addressed due to developmental flight instrumentation deletion.

Evaluation of ground environment instrumentation measurements again verified thermal model analysis data and showed agreement with predicted environmental effects. A voltage spike occurred in left-hand forward field joint heater circuitry at time of heater activation and again during normal heater operations; this spike resulted in immediate heater shutdown by the heater controller. Since there was no accompanying current spike with either voltage spike, the determination was made that the voltage spikes were due to faulty instrumentation readings; therefore, the heater was reactivated. No LCC thermal violations occurred.

Postflight inspection again verified superior performance of the insulation, phenolics, metal parts, and seals. A subsurface void was located on the aft face of inner primary seal of right-hand igniter inner gasket; the void was evidenced by an impression in the seal crown. This void was included in a problem report and elevated to an in-flight anomaly. All combustion gas was contained by the insulation in the field and case-to-nozzle joints.

Recommendations were made concerning improved thermal modeling and measurements as well as incorporation of developmental flight instrumentation on future flights. The rationale for these recommendations, the disposition of all anomalies, and complete result details are contained in this report.

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ACRONYMS

ADCAR . . .	automated data collection and retrieval system	IVBC	integrated vehicle baseline configuration
AT	action time	JPS	joint protection system
CCP	carbon-cloth phenolic	KSC	Kennedy Space Center
CDS	Central Databasing Service	LCC	launch commit criteria
CEI	contract end item	LH	left hand
cg	center of gravity	LRU	line-replaceable unit
D&V	design and verification	LSC	linear shaped charge
DFI	developmental flight instrumentation	LSS	Launch Support Services
DOP	diver operated plug	MLP	mobile launch platform
DWV	dielectric withstanding voltage	ms	millisecond
ECP	engineering change proposal	MSFC	Marshall Space Flight Center
EPDM	ethylene-propylene-diene monomer	MSID	measurement stimulation identification number
EST	eastern standard time	NBR	nitrile butadiene rubber
ET	external tank	NSTS	National Space Transportation System
FBMBT . . .	flex bearing mean bulk temperature	OBR	outer boot ring
FEC	field engineering change	OD	outside diameter
FEWG	Flight Evaluation Working Group	OFI	operational flight instrumentation
FMEA	failure modes and effects analysis	OPT	operational pressure transducer
FSEC	Florida Solar Energy Center	OMI	operations maintenance instructions
GCP	glass-cloth phenolic	OMRSD	Operations and Maintenance Requirements and Specifications Document
GEI	ground environment instrumentation	OPT	operational pressure transducer
GMT	Greenwich mean time	PEEL	postfire engineering evaluation limit
GOX	gaseous oxygen		
GSE	ground support equipment		
HOSC	Huntsville operations Support Center		
HPM	high performance motor		
ID	inside diameter		
IFA	in-flight anomaly		
ips	inches per second		
IR	infrared		

ACRONYMS (Cont)

PMBT . . . propellant mean bulk
temperature
PR problem report
PRCB . . . Program Requirements
Control Board
QM qualification motor
RCN requirements change
notice
RH right hand
RSRM . . . redesigned solid
rocket motor
RSS rotating service
structure
RTD resistance temperature
device
RTV room temperature
vulcanized
S&A safety and arming
SCN specification change
notice
SF safety factor
SII SRM ignition initiator
SIT shuttle interface test
SPM samples per minute
SRB solid rocket booster
SRM solid rocket motor
SSME . . . space shuttle main
engine
STI shuttle thermal imager
TCS thermal control system
TPS thermal protection
system
TVC thrust vector control
USBI . . . United Space Boosters,
Inc.
VAB vehicle assembly
building
3-D three-dimensional

INTRODUCTION

Solid rocket booster (SRB) ignition command time for flight motor set 360H005 was given at 89:220:12:37:00.012 Greenwich Mean Time (GMT) (approximately 8:37 a.m. EDT) on 8 August 1989 at Kennedy Space Center (KSC), Florida. This flight was the 30th space shuttle mission (mission designation STS-28R) and the fifth redesigned solid rocket motor (RSRM) flight. The individual motor identification numbers were 360H005A (left-hand (LH)) and 360H005B (right-hand (RH)), indicating the cases were both half-weights. Additional case configuration details are addressed in Section 4.2.

This volume (Volume I) of this report contains the Thiokol Flight Evaluation Working Group (FEWG) inputs submitted to United Space Boosters, Inc. (USBI) for incorporation into the shuttle prime contractors FEWG report (Document MSFC-RPT-1577). An executive summary of the entire RSRM flight set performance and a one-to-one correlation of conclusions by objectives (and contract end item (CEI) paragraphs) are also included in this report. The detailed component volumes of this report (and the approximate timeline for volume release from the launch date) are listed in Table 1-1.

The subsections of this report volume that were submitted to USBI as part of the FEWG report are so designated with the FEWG report paragraph number.

Table 1-1. Component Volume Release Schedule

<u>Volume</u>	<u>Component Description</u>	<u>Interim Release</u>	<u>Final Release</u>
I	System overview	NA	Approximately 60 days after launch
II	Case	45 days after last field joint demate at KSC Hangar AF	45 days after washout of last segment at Building H-7 of Clearfield facility
III	Insulation	45 days after last field joint demate at KSC Hangar AF	45 days after last factory joint disassembly at H-7
IV	Seals	30 days after last internal nozzle joint demate	30 days after last factory joint disassembly at H-7
V	Nozzle	45 days after last internal nozzle joint demate	90 days after final nozzle liner char and erosion measurements
VI	Igniter	NA	30 days after igniter disassembly at H-7
VII	Joint protection system (heater)	NA	60 days after launch
VIII	Systems tunnel	NA	60 days after launch
IX	Instrumentation	NA	60 days after launch
X	Performance and mass properties	NA	30 days after last factory joint disassembly at H-7
XI	Dynamics (reconstructed loads evaluation)	NA	60 days after receipt of reconstructed loads

2

OBJECTIVES

The fifth Thiokol RSRM flight test objectives were derived from the fifth flight test summary sheet of the Design and Verification (D&V) Plan (TWR-15723C). Such objectives are listed here as contained in the engineering requirements document for RSRM fifth flight (TWR-19073). They are intended to satisfy the requirements of CPW1-3600A (including Addendum G) as listed in parenthesis below.

Qualification Objectives

- A. Ignition interval shall be between 202 and 262 milliseconds with a 40 millisecond environmental delay after ignition command to solid rocket motor (SRM) ignition initiators (SII) in the safety and arming (S&A) device up to a point at which headend chamber pressure has built up to 563.5 psia (3.2.1.1.1.1).
- B. Maximum rate of pressure buildup shall be 115.9 psi for any 10 millisecond interval (3.2.1.1.1.2).
- C. Verify that thrust-time performance falls within requirements of nominal thrust-time curve (3.2.1.1.2.1 Table 1).
- D. Certify that measured motor performance parameters, when corrected to a 60°F propellant mean bulk temperature (PMBT), fall within the nominal value, tolerance, and limits for individual flight motors (3.2.1.1.2.2 Table 2).
- E. With a maximum PMBT difference of 1.4°F between the two RSRMs on a shuttle vehicle, the differential thrust between the two RSRMs shall not be greater than the values given in Table 3 at any time during the periods shown. These differentials are applicable over the PMBT range of +40° to +90°F (3.2.1.1.2.3).
- F. Certify that thrust-time curve complies with impulse requirements (3.2.1.1.2.4).
- G. Certify that specified temperatures are maintained in the case-to-nozzle joint region (3.2.1.2.1.f).

Qualification Objectives (Cont)

- H. Case segment mating joints shall contain a pin retention device (3.2.1.3.g).
- I. Verify that S&A devices perform as required using the specified power supply (3.2.1.6.1.2).
- J. Verify that operational flight instrumentation (OFI) is capable of launch readiness checkout after the ground system has been connected on the launch pad (3.2.1.6.2).
- K. Certify proper operation of the operational pressure transducer (OPT) during flight (3.2.1.6.2.1).
- L. The ground environment instrumentation (GEI) shall monitor the temperature of the SRBs while on the ground at the pad. The GEI is not required to function during flight. These instruments will be monitored on the ground through cables with lift-off breakaway connectors (3.2.1.6.2.3).
- M. When exposed to the thermal environments of 3.2.7.2, the systems tunnel floorplates and cables will be maintained at a temperature at or below that specified in ICD 3-44002 (3.2.1.10.1).
- N. Certify that performance of the field joint heater and sensor assembly maintain the case field joint at 75°F minimum. Field joints shall not exceed 130°F (3.2.1.11.a).
- O. Certify that each field joint heater assembly meets all performance requirements (3.2.1.11.1.2).
- P. Demonstrate isolation of subsystem anomalies, if required on fifth flight (360H005) hardware (3.2.3.3).
- Q. Demonstrate that RSRM is capable of vertical disassembly, if required (3.2.5.1).
- R. The RSRM and its components will be adequately protected, by passive means, against natural environments during transportation and handling (3.2.8.c).
- S. Demonstrate removal and replacement capability of the functional line-replaceable unit (LRU) (3.4.1).

Objectives by Inspection

- A. Inspect all RSRM seals for performance (3.2.1.2).

Objectives by Inspection (Cont)

- B. Inspect seals for satisfactory operation within the specified temperature range that results from natural and induced environments (3.2.1.2.1.b).
- C. Inspect factory joint insulation for accommodation to structural deflections and erosion (3.2.1.2.2.a).
- D. Inspect factory joint insulation for operation within the specified temperature range (3.2.1.2.2.b).
- E. Verify that at least one virgin ply of insulation exists over the factory joint at end of motor operation (3.2.1.2.2.d).
- F. Verify that no leakage occurred through the insulation (3.2.1.2.2.e).
- G. Verify that flexible bearing seals operate within the specified temperature range (3.2.1.2.3.b).
- H. Verify that flexible bearing maintained a positive gas seal between its internal components (3.2.1.2.3.d).
- I. Verify that ignition system seals operate within the specified temperature range (3.2.1.2.4.b).
- J. Verify that nozzle internal seals and exit cone field joint seals operate within the specified temperature range (3.2.1.2.5.b).
- K. Inspect risers for damage or cracks that would degrade the pressure-holding capability of the case (3.2.1.3.c).
- L. Inspect flexible bearing for damage due to water impact (3.2.1.4.6).
- M. Verify that environmental protection plug will withstand space shuttle main engine (SSME) shutdown, if incurred (3.2.1.4.7.b).
- N. Verify performance of the nozzle liner (3.2.1.4.13).
- O. Inspect ignition system seals for evidence of hot gas leakage (3.2.1.5.a).
- P. Inspect igniter for evidence of debris formation or damage (3.2.1.5.2).

Objectives by Inspection (Cont)

- Q. Inspect seals for visible degradation from motor combustion gas (3.2.1.8.1.1.d).
- R. Verify by inspection that insulation met all performance requirements (3.2.1.8.1.1.e).
- S. Inspect insulation material for shedding of fibrous or particulate matter (3.2.1.8.1.1.f).
- T. Inspect joint insulation for evidence of slag accumulation (3.2.1.8.1.1.g).
- U. Inspect thermal protection system (TPS) to assure that there was no environmental damage to the RSRM components (3.2.1.8.2).
- V. Inspect for thermal damage to the igniter chamber and the adapter metal parts (3.2.1.8.3)
- W. Verify that case components are reusable (3.2.1.9.a).
- X. Verify that nozzle metal parts are reusable (3.2.1.9.b).
- Y. Verify through flight demonstration and a postflight inspection that the flexible bearing is reusable (3.2.1.9.c).
- Z. Verify that igniter components are reusable (3.2.1.9.d).
- AA. Verify by inspection that the S&A is reusable (3.2.1.9.e).
- AB. Verify by inspection that the OPTs are reusable (3.2.1.9.f).
- AC. Inspect case factory joint external seal for moisture (3.2.1.12).
- AD. Inspect hardware for damage or anomalies as identified by the Failure Modes and Effects Analysis (FMEA) documents (3.2.3).
- AE. Determine adequacy of the design safety factors, relief provisions, fracture control, and safe life and/or fail-safe characteristics (3.2.3.1).
- AF. Determine adequacy of subsystem redundancy and fail-safe requirements (3.2.3.2).
- AG. Inspect identification numbers of each reusable RSRM part and material for traceability (3.3.1.5).

Objectives by Inspection (Cont)

- AH. Verify the structural safety factor of the case/insulation bond (3.3.6.1.1.2.a).
- AI. Verify by inspection the remaining insulation thickness of the case insulation (3.3.6.1.2.2, 3.3.6.1.2.3, 3.3.6.1.2.4, 3.3.6.1.2.6).
- AJ. Verify by inspection the remaining nozzle ablative thicknesses (3.3.6.1.2.7).
- AK. Verify the nozzle safety factors (3.3.6.1.2.8).
- AL. Inspect metal parts for presence of stress corrosion (3.3.8.2.b).

RESULTS SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

3.1 RESULTS SUMMARY

This section contains an executive summary of the key results from the flight data evaluation and postflight inspection. Additional information and details can be found in the referenced report sections or in the separate component volumes of this report.

3.1.1 In-Flight Anomalies

Two in-flight anomalies (IFA) relating to RSRM motor set 360H005 were identified and they are summarized below.

<u>MSFC IFA No.</u>	<u>Problem Title/ Description</u>	<u>Corrective Action Closure</u>
STS-28-M-1	Indentation on aft face of inner primary seal of RH igniter inner gasket (approximate dimensions: 0.10 in. long by 0.025 in. wide).	An inspection technique to detect subsurface voids will be developed. Gaskets on 360L006, 360L007, and 360L008 were inspected/changed out.
STS-28-M-2	Internal insulation ply separation on the RSRM-5B aft center segment. Noted during postflight hardware inspection. First time recorded occurrence in 78 motors inspected.	Insulation sagged at upper quadrant during layup required emergency vacuum bag operation. Process required methylchloroform double wipe to remove adhesive residue from yellow vinyl tape--was not adequately performed. Partial temporary bags will not be used during insulation layup without an inspection for contamination.

The disposition and closeout statements of the IFAs are included in Section 4.1.

3.1.2 Mass Properties

All SRM weight values were well within the CEI specification limits, as has been the case on all previous RSRM motor sets. Complete mass property values are included in Section 4.3 of this volume and Volume X of this report.

3.1.3 Propulsion Performance (Ballistics)

3.1.3.1 Propellant Burn Rates/Specific Impulse. The delivered burn rate for both motors of flight set 360H005 was 0.369 in./sec (at 82°F and 625 psia), which was 0.001 in./sec lower than predicted. The reconstructed vacuum specific impulse values were 268.4 lbf*sec/lbm for the LH motor and 268.8 lbf*sec/lbm for the RH motor at 82°F, which was within 0.2 percent of the predicted value of 268.3 lbf*sec/lbm.

3.1.3.2 CEI Specification Values. All impulse values, time parameters, and pressure and thrust levels (all corrected to 60°F) again showed excellent agreement with the motor nominal performance requirements. Actual value variations from the allowable CEI specification limits were all within 2 percent, significantly less than the allowable 3-sigma variation. Thrust imbalance was also well within the specification limits for the required time periods.

Due to no developmental flight instrumentation (DFI) on this flight, no high sample rate pressure data were available. Therefore, the CEI specification requirement to verify ignition interval, pressure rise rate, and ignition time thrust imbalance could not be addressed. A complete evaluation of all ballistic parameters is included in Section 4.4 of this volume.

3.1.4 S&A Device

The S&A device safe-to-arm rotation times were all within the minimum 2-sec requirement during the launch countdown. The actual times, as recorded on the S&A device gages, are included in Section 4.10.4 of this volume.

3.1.5 Ascent Loads and Structural Dynamics

Due to the elimination of DFI on motor set 360H005, no evaluation of the RSRM loading or vibration characteristics is possible.

3.1.6 External TPS/Joint Heater Evaluation

Postflight assessment results stated all TPS components to be in very good to excellent condition, with typical flight heat effects and erosion. National Space and Transportation System (NSTS) debris criteria for all missing TPS were not violated.

All six field joint heaters performed adequately and as expected throughout the required operating periods. The secondary left forward field joint heater failed the dielectric withstanding voltage (DWV) test prior to the shuttle interface test (SIT), but it did function properly during the SIT. This heater was not powered up during the actual countdown. Voltage spikes were seen in the LH forward field joint heater circuitry at the time of heater activation and again during normal heater operation. The voltage spikes resulted in immediate heater shutdown by the heater controller. Since there was no accompanying current spike with the voltage spikes, it was determined that the voltage spikes were due to faulty instrumentation readings and the heater was reactivated. A problem report (PR) was generated and the problem was traced to electronics in the mobile launch platform (MLP). A detailed TPS and heater evaluation is in Section 4.8 of this volume.

3.1.7 Aero/Thermal Evaluation

3.1.7.1 On-Pad Local Environments/Thermal Model Verification. The on-pad local environments were indicative of August conditions (74° to 86°F), with the ambient temperatures ranging from 73° to 94°F. Windspeeds were close to predicted values, with the direction primarily from the southwest.

No extreme outward cooling effects from external tank (ET) cryogenic loading were noted--only minor cooling (2° to 3°F) on the inboard region of 360H005B (RH).

3.1.7.2 Launch Commit Criteria/Infrared Readings. No launch commit criteria (LCC) thermal violations were noted; all field and igniter joint heaters performed adequately. The aft skirt purge was temporarily activated for

checkout purposes 16 hours before launch. Because of the warm ambient and component temperatures the purge operation was not permanently activated until T-15 minutes.

Infrared (IR) measurements taken by the IR gun during the T-3 hour ice/debris pad inspection were found to be anomalous and therefore not reported. The shuttle thermal imager (STI) temperature measurements were used along with GEI measurements to monitor SRM surface temperatures.

No thermal evaluation of the aft skirt area (as was done on RSRM Flights 1 through 3) was possible due to DFI elimination. A complete aero/thermal evaluation is in Section 4.8 of this volume.

3.1.8 Instrumentation

All 108 GEI measurements performed properly throughout the prelaunch phase. (All GEI are disconnected by breakaway umbilicals at SRB ignition and are not operative during flight.) All OPTs functioned properly during flight and successfully passed the prelaunch calibration checks. A complete discussion of GEI and all instrumentation is in Section 4.10 of this volume.

3.1.9 Postflight Hardware Assessment

3.1.9.1 Insulation. Postflight evaluation again verified excellent insulation performance, showing that the insulation effectively contained the motor combustion gas in the two case-to-nozzle joints and six field joints. All weatherseal unbonds resulted from splashdown loads. No gas paths through the case-to-nozzle joint polysulfide adhesive or any other anomalous joint conditions were identified. The internal insulation in all six of the case field joints also performed as designed, with no anomalous conditions. There were no recordable clevis edge separations (over 0.1 in.). No evidence of hot gas penetration through any of the acreage insulation or severe erosion patterns were identified. A ply separation was identified in the internal insulation of the RH aft center segment, but it did not affect motor performance. The separation was made into an IFA. For a complete discussion, see Section 4.1 of this volume. A complete insulation performance evaluation is in Section 4.11.1 of this volume and Volume III of this report.

3.1.9.2 Case. Overall, fretting on motor set 360H005 was lighter than usual, with the exception of the center field joints. The deepest pit was seen on the RH center field joint and measured 0.011 inch.

Evaluation of the steel case indicated that the hardware performed as expected during flight. No new damage was noted on the LH stiffener stubs or ET attach stubs. All three stiffener ring sections on the RH motor were damaged on the 90-deg end. Eight RH ring-to-stub bolts were sheared off from the 92-deg through 106-deg locations of each section. Each ring section had cracks through the boltholes at 108 deg, with the forward ring having the worst damage. No cracks were noted in the RH case stiffener or ET attach stubs.

The complete case evaluation results are in Section 4.11.2 of this volume and Volume II of this report.

3.1.9.3 Seals. All internal seals performed well, with no heat effects, erosion, or hot gas leakage evident. One subsurface void on the aft face of the inner primary seal of the RH igniter inner gasket resulted in an IFA. Sections 4.1 and 4.11.3.6 contain a complete discussion of this IFA. No motor pressure reached the field or case-to-nozzle joint seals. Evaluation of the field and factory joints indicated that the internal seals performed as expected during flight. A complete evaluation of seals performance is in Section 4.11.3 of this volume and Volume IV of this report.

3.1.9.4 Nozzle/Thrust Vector Control Performance. Postflight evaluation indicated both nozzles performed as expected during flight, with typical smooth and uniform erosion profiles. A complete evaluation is in Section 4.11.4 of this volume and Volume V of this report.

3.2 CONCLUSIONS

Listed below are the conclusions as they relate specifically to the objectives and the CEI paragraphs. Also included with the conclusion is the report section (in parentheses) where additional information can be found.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>																				
Certify that the thrust-time performance falls within the requirements of the nominal thrust-time curve.	3.2.1.1.2.1 (See nominal thrust-time curve)	<u>Certified.</u> The thrust-time performance was within the nominal thrust-time curve. (Figure 4.4-1).																				
Certify that the measured motor performance parameters, when corrected to a 60°F PMBT, fall within the nominal value, tolerance, and limits for individual flight motors.	3.2.1.1.2.2 The delivered performance values for each individual motor when corrected to a 60°F PMBT shall not exceed the limits specified...	<u>Partially Certified.</u> All measurable motor performance values were well within the specification requirements. (Tables 4.4-2 and 4.4-3.) The ignition interval and rise rates could not be measured due to DFI elimination.																				
Certify that the thrust-time curve complies with impulse requirements.	3.2.1.1.2.4 Impulse Gates. <table><tr><th>Time (sec)</th><th>Total Impulse (10E6 lb-sec)</th></tr><tr><td>20</td><td>63.1 minimum</td></tr><tr><td>60</td><td>172.9-1%+3%</td></tr></table> Action Time (AT) 293.8 minimum	Time (sec)	Total Impulse (10E6 lb-sec)	20	63.1 minimum	60	172.9-1%+3%	<u>Certified.</u> The nominal thrust-time curve values are listed below. <table><tr><th rowspan="2">Time (sec)</th><th colspan="2">Value</th></tr><tr><th>LH</th><th>RH</th></tr><tr><td>20</td><td>66.69</td><td>65.57</td></tr><tr><td>60</td><td>177.20</td><td>177.14</td></tr><tr><td>AT</td><td>297.00</td><td>297.27</td></tr></table> (Table 4.4-1)	Time (sec)	Value		LH	RH	20	66.69	65.57	60	177.20	177.14	AT	297.00	297.27
Time (sec)	Total Impulse (10E6 lb-sec)																					
20	63.1 minimum																					
60	172.9-1%+3%																					
Time (sec)	Value																					
	LH	RH																				
20	66.69	65.57																				
60	177.20	177.14																				
AT	297.00	297.27																				
Certify that specified temperatures are maintained in the case-to-nozzle joint region.	3.2.1.2.1.f Case-to-nozzle joint O-rings shall be maintained within the temperature range as specified in ICD 2-OA002. (75° to 120°F)	<u>Certified.</u> Temperature ranges in the case-to-nozzle joint region are listed below. <table><tr><td>RH</td><td>82° to 85°F</td></tr><tr><td>LH</td><td>82° to 83°F</td></tr></table> (Table 4.8-4)	RH	82° to 85°F	LH	82° to 83°F																
RH	82° to 85°F																					
LH	82° to 83°F																					

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Certify that the ignition interval is between 202 and 262 ms, with a 40-ms environmental delay after ignition command.	3.2.1.1.1.1 The ignition interval shall be between 202 and 262 ms with a 40-ms environmental delay after ignition command to the SII in the S&A device up to a point at which the headend chamber pressure has built up to 563.5 psia.	<u>Unable to Certify.</u> Due to DFI elimination (high sample rate pressure transducer).
Certify that the pressure rise rate meets specification requirements.	3.2.1.1.1.2 The maximum rate of pressure buildup shall be 115.9 psi for any 10-ms interval.	<u>Unable to Certify.</u> Due to DFI elimination (high sample rate pressure transducers).
Certify that the motor thrust differential meets specifications requirements.	3.2.1.1.2.3 With a maximum PMBT difference of 1.4°F between the two RSRMs on a shuttle vehicle, the differential thrust between the two RSRMs shall not be greater than the values given in Table III at any time during the periods shown. These differentials are applicable over PMBT range of +40° to +90°F.	<u>Unable to Certify.</u> Due to DFI elimination (high sample rate pressure transducers).
Certify that the S&A devices perform as required using the specified power supply.	3.2.1.6.1.2 Power Supply. The S&A device shall meet all performance requirements...in accordance with ICD 3-44005.	<u>Certified.</u> The rotation and arming times of both S&A devices were within the required limits. (Section 4.10).

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Certify that the OFI is capable of launch readiness checkout after the ground system has been connected on the launch pad.	3.2.1.6.2 Instrumentation. The OFI shall be capable of launch readiness check-out after ground system connection on the launch pad.	<u>Certified.</u> The 0 percent and 75 percent calibration checks of the OFI verified launch readiness after ground system connection on the launch pad (Section 4.10).
Certify proper operation of the OPT during flight.	3.2.1.6.2.1 The OPT shall monitor the chamber pressure of the RSRMs over the range from 0 to 1,050 \pm 15 psi. They shall operate in accordance with ICD 3-44005...	<u>Certified.</u> The OPTs properly monitored the chamber pressure and operated in accordance with ICD 3-44005. Recorded pressure data and values are discussed in Section 4.4 of this volume.
Certify that the systems tunnel properly: 1) attaches to the case, 2) accommodates the government-furnished equipment (GFE) and linear shaped charge (LSC), and 3) provides OFI, GEI, and heater cables.	3.2.1.10.1 When exposed to the thermal environments of 3.2.7.2, the tunnel floorplates and tunnel cables will be maintained at a temperature at or below that specified in ICD 3-44002.	<u>Certified.</u> Postflight evaluation showed no evidence of heat damage to the systems tunnel or adjacent cork, cables, and seams (Table 4.8-3). Proper case attachment and accommodation of the GFE, LSC, and cabling was also verified. A detailed systems tunnel evaluation is in Volume VIII of this report.
Certify the performance of the field joint heater and the sensor assembly so it maintains the case field joint at 75°F minimum. Field joints shall not exceed 130°F.	3.2.1.11.a The case field joint external heater and sensor assembly shall maintain the case field joint O-ring seals between 75° and 120°F at launch...	<u>Certified.</u> The joint heaters maintained all field joints between 92° and 103°F during the prelaunch period (Table 4.8-4).

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Certify that each field joint heater assembly meets all performance requirements.	3.2.1.11.1.2 Power Supply. Each field joint external heater assembly shall meet all performance requirements... as defined in ICD 3-44005.	<u>Certified.</u> All the field joint external heaters met all the performance requirements, with the exception of the secondary left forward field joint heater which failed the DWV test. However, primary heater functioned so use of the secondary was not required. (Section 4.8.3).
Demonstrate isolation of subsystem anomalies if required on fifth flight (360H005) hardware.	3.2.3.3 Isolation of anomalies of time-critical functions shall be provided such that a faulty subsystem element can be deactivated without disrupting its own or other subsystems.	No subsystem anomalies of time-critical functions were detected on flight set 360H005.
Demonstrate RSRM capability of assembly/disassembly in both the vertical and horizontal positions.	3.2.5.1 The RSRM shall be capable of assembly/disassembly in both the vertical and horizontal positions. The RSRM shall be capable of vertical assembly in a manner to meet the alignment criteria of USBI-10183-0022 without a requirement for optical equipment.	RSRM vertical assembly in accordance with USBI-10183-0022 was demonstrated in the vehicle assembly building (VAB) prior to pad rollout. No vertical disassembly was required. Postflight horizontal disassembly was accomplished at Hangar AF of Clearfield, UT, facility.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Demonstrate that the RSRM and its components are protected against environments during transportation and handling.	3.2.8.c The RSRM and its components...are adequately protected, by passive means, against natural environments during transportation and handling.	The LH and RH aft segments (including nozzle components) experienced an extremely cold thermal environment in Corinne, UT, violating minimum component temperatures limits. A preflight thermal analysis was done to verify the integrity of the components (TWR-19345). Postflight inspection results revealed no damage to motor set 360H005 and its components as a result of environmental exposure during transportation, verifying the analysis.
Demonstrate remove and replace capability of the functional LRU.	3.4.1 The maintenance concept shall be to "remove and replace"...in a manner which will... prevent deterioration of inherent design levels of reliability and operating safety at minimum practical costs.	No LRU anomalies were detected on motor set 360H005; therefore, no LRU changeouts were required.
Certify by inspection all RSRM seals performance.	3.2.1.2 Redundant, verifiable seals shall be provided for each pressure vessel leak path. Both the primary and secondary seals shall provide independent sealing capability through the entire ignition transient and motor burn without evidence of blowby or erosion.	<u>Certified.</u> No motor pressure reached any of the field or case-to-nozzle joint seals. All seals that did have motor pressure reach them showed no evidence of heat effect, erosion, or blowby. (Section 4.11.3).

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Certify by inspection that the factory joint insulation accommodates structural deflections and erosion.	3.2.1.2.2.a Sealing shall accommodate any structural deflections or erosion which may occur.	<u>Certified.</u> The factory joint insulation remained sealed and accommodated all deflection and erosion. (Section 4.11.1).
Certify that at least one virgin ply of insulation over factory joint remained at end of motor operation.	3.2.1.2.2.d The insulation shall provide one or more virgin ply coverage at end of motor operation. The design shall perform the seal function throughout SRM operation.	<u>Certified.</u> Preliminary inspections indicate adequate factory joint insulation ply coverage. (Section 4.11.1). Detailed insulation inspection results are in Volume III of this report.
Certify that the field and case-to-nozzle joint seals, factory joint insulation, flex bearing seals, ignition system seals, and nozzle internal seals operate within the specified temperature range resulting from the natural and induced environments.	3.2.1.2.1.b Field and Nozzle/Case Joint Seals... 3.2.1.2.2.b Factory Joint Insulation... 3.2.1.2.3.b Flex Bearing Seals... 3.2.1.2.4.b Ignition System Seals... 3.2.1.2.5.b Nozzle Internal Seals... ...shall be capable of operating within a temperature range resulting from all natural and induced environments...all manufacturing processes, and any motor induced environments.	<u>Certified.</u> All field joint and case-to-nozzle joint seals, ignition system seals, and internal nozzle seals operated within all induced environments and showed no evidence of heat effects, erosion, or blowby. (Section 4.11.3). Evaluation indicates no anomalies with the factory joint insulation (Section 4.11.1), or the flex bearing internal seals. A detailed flex bearing evaluation is in Volume V of this report.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Certify that no leakage occurred through the insulation.	3.2.1.2.2.e The insulation used as a primary seal shall be adequate to preclude leaking through the insulation.	<u>Certified.</u> Preliminary inspections showed no evidence of leakage through the factory joint insulation. (Section 4.11.1). Detailed postflight evaluations are completed at Building H-7 of Clearfield, UT, facility. Detailed results are in Volume III of this report.
Certify by inspection that no gas leaks occurred between the flex bearing internal components.	3.2.1.2.3.d The flex bearing shall maintain a positive gas seal between its internal components.	<u>Partially Certified.</u> Preliminary inspection indicates the flex bearing maintained positive seal within its internal components. Detailed inspection is to be completed during flex bearing acceptance testing.
Inspect the risers for damage or cracks that would degrade the pressure holding capability of the case.	3.2.1.3.c The case shall contain risers for attaching the ET/SRB aft attach ring as defined in ICD 3-44004. The risers shall be part of the pressurized section of the case and shall not degrade the integrity of the case.	No damage or adverse effects to the ET attach risers was noted during post-test inspection. Preliminary case inspection results are in Section 4.11.2, and final case evaluation is in Volume II of this report.
Inspect the case segment mating joints for the pin retention device.	3.2.1.3.g The case segment mating joints shall contain a pin retention device.	The pin retention devices on all joints performed as designed. (Section 4.11.2). Detailed results are in Volume II of this report.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Inspect the flex bearing for damage due to water impact.	3.2.1.4.6 The nozzle assembly shall incorporate a nozzle snubbing device suitable for preventing flex bearing damage resulting from water impact and shall not adversely affect the nozzle assembly vectoring capability.	Preliminary inspections indicate no anomalous conditions on the 360H005A or 360H00B flex bearing.
Inspect the nozzle for the presence of the environmental protection plug.	3.2.1.4.7.a The nozzle assembly shall contain a covering and/or plug to protect the RSRM...during storage after assembly.	Both nozzle assemblies contained an environmental protection plug, which burst into multiple pieces upon motor ignition.
Certify that the environmental protection plug will withstand space shuttle main engine (SSME) shutdown, if incurred.	3.2.1.4.7.b The nozzle assembly shall contain a covering and/or plug to protect the RSRM...in the event of an on-pad SSME shutdown prior to SRB ignition.	<u>Not Required to Certify.</u> No SSME shutdown was required during the actual launch sequence.
Certify the performance of the nozzle liner. <u>Note:</u> SCN 49 proposes to change the CEI paragraph wedgeout requirement from "greater than 0.250 in. deep" to "yield a positive margin of safety".	3.2.1.4.13 The nozzle flame front liners shall prevent the formation of: a. Pockets greater than 0.250 in. deep (as measured from the adjacent nonpocketed areas). b. Wedgeouts greater than 0.250 in. deep. c. Prefire anomalies except as allowed by TWR-16340.	<u>Certified.</u> No nozzle flame front liner erosion pockets greater than 0.25 in. were noted. All wedgeouts observed occurred postburn and do not affect liner performance. No prefire anomalies were found. (Section 4.11.4).

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Inspect the ignition system seals for evidence of hot gas leakage.	3.2.1.5.a The ignition system shall preclude hot gas leakage during and subsequent to motor ignition.	All ignition system seals, gaskets, and sealing surfaces showed no evidence of heat effects, erosion, or blowby. (Section 4.11.3).
Inspect the igniter for evidence of debris formation or damage.	3.2.1.5.2 ...the igniter hardware and materials shall not form any debris...	Preliminary indications show no evidence of any igniter debris formation. A complete evaluation is in Volume VI of this report.
Certify that the GEI can monitor the temperature of the SRBs while on the ground at the pad.	3.2.1.6.2.3 The GEI shall monitor the temperature of the SRBs while on the ground...	<u>Certified.</u> Extensive monitoring of the GEI was done during the countdown to access the SRM thermal environment and LCC. Detailed results are discussed in Section 4.8 of this volume.
Inspect the seals for visible degradation from motor combustion gas.	3.2.1.8.1.1.d Insulation shall protect primary and secondary seals from visible degradation from motor combustion gas.	All motor combustion gas was contained by the insulation J-leg on the six field joints and the polysulfide adhesive on the two case-to-nozzle joints. No seals showed evidence of motor combustion gas degradation. (Section 4.11.1).
Certify by inspection that the insulation met all performance requirements.	3.2.1.8.1.1.e The insulation shall... meet all performance requirements under worst manufacturing tolerances and geometry changes during and after assembly and throughout motor operation.	<u>Certified.</u> Preliminary inspection indicates the insulation met all the performance requirements. (Section 4.11.1). Detailed inspection results are in Volume III of this report.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Inspect insulation material for shedding of fibrous or particulate matter.	3.2.1.8.1.1.f Insulation materials shall not shed fibrous or particulate matter during assembly which could prevent sealing.	No shedding of fibrous or particulate matter during assembly was detected. Detailed inspection results are in Section 4.11.1 of this volume and Volume III of this report.
Inspect the joint insulation for evidence of slag accumulation.	3.2.1.8.1.1.g The joint insulation shall withstand slag accumulation during motor operation.	No evidence of insulation damage due to slag accumulation was observed. Detailed inspection results are in Section 4.11.1 of this volume and Volume III of this report.
Inspect the TPS to ensure that there was no environmental damage to the RSRM components.	3.2.1.8.2 TPS shall ensure that the mechanical properties of the RSRM components are not degraded when exposed to the environments...	Postflight inspection revealed excellent TPS condition with no violation of any NSTS debris criteria. No thermal degradation of any RSRM component was noted (Section 4.8.3).
Inspect for thermal damage to the igniter chamber and the adapter metal parts.	3.2.1.8.3 The igniter insulation shall provide thermal protection for the main igniter chamber and adapter metal parts to ensure that RSRM operation does not degrade their functional integrity or make them unsuitable for refurbishment.	Preliminary investigation revealed no thermal damage to the igniter due lack of insulation functionality. Igniter details are in Volume VI of this report.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Certify that the case components are reusable.	3.2.1.9.a Reusability of... Case - Cylindrical segments, stiffener segments, attach segments, forward and aft segments (domes), stiffener rings, clevis joint pins.	<u>Cannot Be Completely Certified at This Time.</u> All case component previous use history is in Section 4.2. No damage was noted to any cylindrical segments, attach segments, forward and aft domes, clevis joint pins, or the stiffener rings and segments on 360H005A (LH). The 360H005B (RH) motor stiffener ring sections were damaged on the 90-deg end due to splashdown loads. (Section 4.11.2). Reuse criteria is not established until after refurbishment. Detailed case component inspection results are in Volume II of this report.
Certify that the nozzle metal parts are reusable.	3.2.1.9.b Reusability of... Nozzle metal parts - boss attach bolts.	<u>Cannot Be Completely Certified at This Time.</u> All nozzle metal part previous use history is in Section 4.2. Preliminary observations showed no damage or corrosion to any nozzle reusable metal parts. (Section 4.11.4). Any nozzle metal parts that are determined not to be reusable are discussed in Volume V of this report.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Certify through flight demonstration and a postflight inspection that the flex bearing is reusable.	3.2.1.9.c Reusability of... Flex bearing system - Reinforced shims and end rings, elastomer materials.	<u>Cannot Be Completely Certified at This Time.</u> The flex bearing previous use history is in Section 4.2. No apparent anomalies were observed with the 360H005A (LH) or 360H005B (RH) flex bearing (Section 4.11.4). Final reuse criteria cannot be determined until after flex bearing acceptance testing.
Certify that the igniter components are reusable.	3.2.1.9.d Reusability of... Igniter - Chamber, adapter, igniter port, special bolts.	<u>Cannot Be Completely Certified at This Time.</u> All igniter component previous use history is in Section 4.2. Preliminary postflight inspection revealed nothing that would adversely affect reuse of any igniter part. Detailed inspection result are in Volume VI of this report.
Certify by inspection that the S&A device is reusable.	3.2.1.9.e Reusability of... Safe & Arm Device	<u>Cannot Be Completely Certified at This Time.</u> The S&A device previous use history is in Section 4.2. Preliminary postflight inspection revealed nothing that would adversely affect reuse of any S&A device part. Detailed inspection results are in Volume VI of this report.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Certify by inspection that the OPTs are reusable.	3.2.1.9.f Reusability of... Transducers	<u>Cannot Be Completely Certified at This Time.</u> The OPT previous use history is in Section 4.2. All pressure data and preliminary post-flight inspection indicate no issues that would adversely affect OPT reuse. Final OPT reuse criteria is established after refurbishment and calibration by the Metrology Laboratory.
Inspect the case factory joint external seal for moisture.	3.2.1.12 The factory joint external seal shall prevent the prelaunch intrusion of rain into the factory joints from the time of assembly of the segment until launch... The factory joint seal shall remain intact through flight and, as a goal, through recovery.	The external weatherseal protected the case adequately from assembly until launch. Two of the 14 factory joint weatherseals showed signs of aft edge unbonds resulting from splashdown. A detailed weatherseal evaluation is in Volume III of this report.
Inspect the hardware for damage or anomalies as identified by the FMEA.	3.2.3 The design shall minimize the probability of failure, taking into consideration the potential failure modes identified and defined by FMEA.	No hardware damage or anomalies identified by FMEA were found. Specific inspection results are in the individual component volumes of this report.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Determine the adequacy of the design safety factors (SF), relief provisions, fracture control, and safe-life and/or fail-safe characteristics.	3.2.3.1 The primary structure, thermal protection, and pressure vessel subsystems shall be designed to preclude failure by use of adequate design SFs, relief provisions, fracture control, and safe-life and/or fail-safe characteristics.	Postflight inspections verified adequate design SFs, relief provisions, fracture control, and safe-life and/or fail-safe characteristics for the primary structure, thermal protection, and pressure vessel subsystems as documented in this volume and the component volumes of this report.
Determine the adequacy of subsystem redundancy and fail-safe requirements.	3.2.3.2 The redundancy requirements for subsystems... shall be established on an individual subsystem basis, but shall not be less than fail-safe...	No primary subsystem failure was noted; thus subsystem redundancy and fail-safe requirements were not determined.
Inspect the identification number of each reusable RSRM part and materials for traceability.	3.3.1.5 Traceability shall be provided by assigning a traceability identification to each RSRM part and material and providing a means of correlating each to its historical records...	Inspection numbers for traceability of each RSRM part and material are provided, and are maintained in the Automated Data Collection and Retrieval (ADCAR) computer system. The past history of all RSRM parts used is in Section 4.2 of this volume.
Verify the structural SF of the case-to-insulation bond.	3.3.6.1.1.2.a The structural SF for the case-to-insulation bonds shall be 2.0 minimum during the life of the RSRM.	Verification of a 2.0 SF cannot be done by inspection; however, flight performance verified a SF of at least 1. Case-to-insulation bond and adhesive bond SF of 2.0 are verified by analysis and documented in TWR-16961.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Verify by inspection the remaining insulation thickness of the case insulation.	3.3.6.1.2.2 The case insulation shall have a minimum design SF of 1.5, assuming normal motor operation, and 1.2, assuming loss of a castable inhibitor.	Detailed postflight insulation inspections are performed at Building H-7 of the Clearfield, UT, facility. Results and verification of SFs are in Volume III of this report.
(Objective continued)	3.3.6.1.2.3 Case insulation adjacent to metal part field joints, case-to-nozzle joints, and extending over factory joints shall have a minimum SF of 2.0.	See above statement.
(Objective continued)	3.3.6.1.2.4 Case insulation in sandwich construction regions (aft dome and center segment aft end) shall have a minimum SF of 1.5.	See above statement.
(Objective continued)	3.3.6.1.2.6 Insulation performance shall be calculated using actual pre- and post-motor operation insulation thickness measurements.	Standard measurement techniques were used for final evaluation, as discussed in Volume III of this report.
Verify by inspection the remaining nozzle ablative thicknesses.	3.3.6.1.2.7 The minimum design safety factors for the nozzle assembly primary ablative materials shall be as listed below... (Values not included here because detailed results are not available at this writing).	Preliminary inspections indicate nozzle ablative thicknesses were within design SFs. (Section 4.11.1)). Detailed results are in Volume V of this report.

<u>Objective</u>	<u>CEI Paragraph</u>	<u>Conclusions</u>
Verify the nozzle SFs.	3.3.6.1.2.8 The nozzle performance margins of safety shall be zero or greater...	Verification of SFs cannot be done by inspection. Nozzle margins of safety will be discussed in Volume V of this report.
Inspect metal parts for presence of stress corrosion.	3.3.8.2.b The criteria for material selection in the design to prevent stress corrosion failure of fabricated components shall be in accordance with MSFC-SPEC-522 and SE-019-094-2H.	Inspection of metal parts for the presence of stress corrosion cannot be done visually but will be accomplished during refurbishment. Any stress corrosion found will be reported in Volume II of this report.

3.3 RECOMMENDATIONS

Following are the recommendations made concerning flight motor set 360H005. Additional background information can be in the referenced sections.

3.3.1 General Recommendations

It is recommended to continue the use of DFI on future RSRM flight motors. The DFI will be used to verify SF, verify CEI specification requirements, validate models, and provide additional data for engineering evaluation.

3.3.2 Aero/Thermal Recommendations

(Additional information in Section 4.8.4).

3.3.2.1 GEI Prediction. Additional model enhancement is recommended for the ET attach ring, field joint, factory joint, systems tunnel, igniter, and nozzle regions in order to improve predictions. These tasks would be encompassed by the global model.

3.3.2.2 GEI Prediction Model Availability. It is recommended that the above-mentioned models (including the three-dimensional (3-D) SRM model) be made available for use at Marshall Space Flight Center (MSFC). This would allow Thiokol thermal personnel the opportunity to support launch countdowns at the

Huntsville Operations Support Center (HOSC) with real-time PMBT, GEI, and component prediction updates. This would also allow MSFC thermal personnel the same modeling capabilities.

3.3.2.3 Aft Skirt Conditioning. It is recommended that the aft skirt conditioning gas temperature be monitored as it enters the aft skirt compartment. During cold weather this would allow the use of a higher operating temperature and at the same time not violate the 115°F maximum within the compartment.

3.3.2.4 GEI Accuracy. It is recommended that the GEI data collection accuracy be increased by reducing the gage range and increasing the digital word length. The real fidelity of the KSC ground support equipment (GSE) could then be quantified and conceivably replaced if determined to be inadequate.

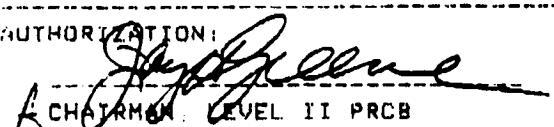
3.3.2.5 Local Chilling. Based on data from STS-28, STS-29R, and STS-30R, local cooling does occur. It is recommended that a method be developed to accurately quantify the chill effect.

3.3.2.6 IR Measurements. It is recommended with future flights, that half-hour STI-versus-GEI direct comparisons be made and documented. (Comparisons with GEI are within acceptable margins for STI data, but are questionable and unpredictable for IR gun data).

FLIGHT EVALUATION RESULTS AND DISCUSSION

4.1 RSRM IN-FLIGHT ANOMALIES (FEWG REPORT PARAGRAPH 2.1.2)

The summary sheets for two IFAs pertaining to flight motor set 360H005 follow. The IFA description, discussion, conclusion, corrective actions, and closeout signature of the Level II Program Requirements Control Board (PRCB) chairman are included. No IFA was considered to be a flight constraint, but the STS-28-M-1 IFA resulted in the inspection and changeout of the gaskets on 360L006, 360L007, and 360L008.

PCIN 44800	- NSTS PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 01 OF 02
PCBD S44800N		PCB DATE 09/28/89
CHANGE TITLE RIGHT SRM INNER IGNITER GASKET INDENTATION OF AFT PRIMARY SEAL (IFA)		
CHANGE PROPOSAL(S) NO. AND SOURCE STS-28 ANOMALY TRACKING LIST FLIGHT PR NO. STS-28-M-1		DOCUMENTS AFFECTED (NO., TITLE, PARA)
INITIATED BY: MSFC-EP73/E. CARRASQUILLO		SUBMITTED BY: MSFC-SA42/R. MITCHELL
LEVEL II BASELINE CHANGE DIRECTION:		OPR: WA ELW/LS BOARD: DAILY
PCBD S44800N IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS-28 ANOMALY NUMBER STS-28-M-1 PER THE FOLLOWING RATIONALE:		
DISCUSSION:		
<p>DURING POSTFLIGHT INSPECTION OF THE RIGHT SRM IGNITER, A SMALL INDENTATION WAS FOUND AT 220 DEGREES ON THE INNER PRIMARY SEAL (AFT SIDE) OF THE INNER GASK-O-SEAL. THE CROWN OF THE INNER PRIMARY SEAL WAS DEPRESSED INWARD AND THE INDENTATION MEASURED APPROXIMATELY 0.100" CIRCUMFERENTIALLY BY 0.025" RADIALY. NO PRESSURE REACHED THE DEFECTIVE SEAL (NO BLOWHOLE THROUGH PUTTY). CONCERN IS THAT SUCH AN ANOMALY WOULD DECREASE THE LOCALIZED GASK-O-SEAL RESILIENCY WHICH COULD ALLOW BLOWBY AT IGNITION.</p>		
CONCLUSIONS:		
<p>SOME OF THE GASK-O-SEALS INSTALLED ON FLIGHT MOTORS MAY HAVE A SIMILAR ANOMALY AND MAY NOT SEAL. ALL SUSPECT GASK-O-SEALS WILL HAVE TO BE REMOVED AND REINSPECTED OR REPLACED.</p>		
AUTHORIZATION:		09/28/89
 CHAIRMAN, LEVEL II PCB		DATE
BARS RPT 6020		BARS NSTS FORM 4003

PCIN 44800	NATIONAL SPACE SHUTTLE PROGRAM DOCUMENT CONTINUATION SHEET	PAGE 02 OF 02
S44800N		OFFICE:
DOCUMENT: S44800N		DATE 09/28/89

CORRECTIVE ACTION:

1. DEVELOP METHOD TO SCREEN GASK-O-SEALS.
 - A. USE ONLY PREVIOUSLY USED GASK-O-SEALS THAT HAVE BEEN INSPECTED IMMEDIATELY AFTER REMOVAL FROM COMPRESSION.
 - B. IMPLEMENT PLEXIGLASS INSPECTION TECHNIQUE TO VISUALLY DETECT GASK-O-SEAL FLAWS UNDER COMPRESSION.
 - C. INVESTIGATE OTHER NDE METHODS SUCH AS X-RAY, CATSCAN, SHEAROGRAPHY, ETC.
2. ASSURE VENDOR MANUFACTURING PROCESS PROVIDES ACCEPTABLE GASK-O-SEAL.

EFFECTIVITY: STS-28

LEVEL II IMPACTS AUTHORIZED BY THIS DIRECTION: --WEIGHT: NONE,
--SCHEDULE: NONE, --COST: NONE.

PCIN 44800	NSTS PROGRAM REQUIREMENTS	PAGE 01 OF 02
PRCBD S44800U	CONTROL BOARD DIRECTIVE - LEVEL II	PRCB DATE 10/06/89
CHANGE TITLE INTERNAL INSULATION PLY SEPARATIONS ON THE RSRM-5B AFT CENTER SEGMENT (IFA)		
CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO., TITLE, PARA)	
STS-28 ANOMALY TRACKING LIST FLIGHT STS-28-M-2		
INITIATED BY: THIOKOL/C. RALSTON	SUBMITTED BY: MSFC SA42/R. MITCHELL	
LEVEL II BASELINE CHANGE DIRECTION:	OPR: WA	MBE/LS BOARD: DAILY
PRCBD S44800U IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS 28 ANOMALY NUMBER STS-28-M-2 PER THE FOLLOWING RATIONALE:		
DISCUSSION:		
<p>A PLY SEPARATION WAS DETECTED WITHIN THE INTERNAL INSULATION OF THE RIGHT SRM AFT CENTER SEGMENT (360H005B). THE SEPARATION MEASURED 11.5" CIRCUMFERENTIAL LENGTH X 1.1" AXIAL LENGTH X 0.05" HIGH. THE AXIAL LENGTH INCREASED TO 2.0" UPON PULLING THE SEPARATION WITH PLIERS (ADHESIVE FAILURE) AND TRANSITIONED INTO A COHESIVE FAILURE THEREAFTER. FURTHER INSPECTION OF THE INSULATION AT THE SAME LONGITUDINAL LOCATION REVEALED OTHER PLY SEPARATIONS OF VARYING LENGTH (3"-5") SPACED INTERMITTENTLY AROUND THE CIRCUMFERENCE. THIS IS THE FIRST TIME THAT THIS ANOMALY HAS BEEN RECORDED OUT OF 78 MOTORS INSPECTED.</p>		
CONCLUSIONS:		
<p>CONTAMINATION WAS SUSPECTED IN THE AREA OF THE SEPARATIONS. THE LOCATION AND TYPE OF CONTAMINATION WERE POSITIVELY IDENTIFIED BY DISSECTION AND LABORATORY TESTS. THE FTIR TEST ANALYSIS RESULTS CONFIRMED THAT THE CONTAMINANT IS AN ADHESIVE RESIDUE FROM THE YELLOW VINYL TAPE USED DURING THE EMERGENCY VACUUM BAGGING PROCESS (DISCUSSED BELOW). A REVIEW OF PLANNING CONFIRMED THAT THE YELLOW VINYL TAPE WAS INSTALLED AT THIS LOCATION.</p>		
(CONCLUSION CONTINUED ON PAGE 02)		
AUTHORIZATION:		
AS/JAY H. GREENE, FOR	10/06/89	
CHAIRMAN, LEVEL II PRCB	DATE	
BARS RPT 8020	BARS NSTS FORM 4003	

PCIN 44800	NATIONAL	PAGE 02 OF 02
544800U	SPACE SHUTTLE PROGRAM	OFFICE:
DOCUMENT: 544800U	DOCUMENT CONTINUATION SHEET	DATE 10/06/80

CONCLUSION (CONTINUED):

NORMAL INSULATION PROCESSING CALLS FOR A SIX HOUR FULL-SEGMENT VACUUM BAG DEBULK JUST BEFORE THE FLAP BULB REGION IS LAYED UP. DURING INSULATION LAYUP OF THE AFT CENTER SEGMENT, A TEMPORARY EMERGENCY VACUUM BAG WAS NEEDED WHEN THE INSULATION STARTED TO SAG BEFORE THE NORMAL VACUUM DEBULK COULD BE PERFORMED. THIS OPERATION WAS DOCUMENTED IN PLANNING. THE PROCESS REQUIRED A METHYL CHLOROFORM DOUBLE WIPE TO REMOVE ANY REMAINING RESIDUE. RESULTS INDICATE THIS PROCESS WAS NOT ADEQUATELY PERFORMED.

CORRECTIVE ACTION:

PARTIAL TEMPORARY BAGS (EMERGENCY VACUUM PROCESS) WILL NOT BE USED DURING INSULATION LAYUP WITHOUT AN INSPECTION FOR CONTAMINATION.

EFFECTIVITY: STS 29

LEVEL II IMPACTS AUTHORIZED BY THIS DIRECTION: WEIGHT: NONE, --SCHEDULE: NONE, --COST: NONE.

4.2 RSRM CONFIGURATION SUMMARY (FEWG REPORT PARAGRAPH 2.1.3.2)

4.2.1 SRM Reuse Hardware

The case segment reuse histories for flight motors 360H005A and 360H005B are in Figures 4.2-1 and 4.2-2, respectively. Figures 4.2-3 through 4.2-6 show the left and right igniter and nozzle part reuse, respectively. Nozzle snubber segments were new. Stiffener ring reuse is in Figure 4.2-7 and Table 4.2-1.

Hydroproofs	Previous Use	A LEFT	
3	ETM-1A	S/N 0000038R1	Case Segment, Fwd Dome P/N 1U51473-03
5	DM-9	S/N 000001R1	Case Segment, Cylinder P/N 1U50131-13
4	DM-9	S/N 0000002R1	Case Segment—Capture Cylinder, Std Weight P/N 1U52983-02
5	SRM-10A,20A;DM-9	S/N 0000042R3	Case Segment, Cylinder Lightweight P/N 1U50717-05
5	QM-6	S/N 0000015R1	Case Segment—Capture Cylinder, Lightweight P/N 1U52982-03
5	SRM-11A,21A;DM-9	S/N 0000045R3	Case Segment, Cylinder Lightweight P/N 1U50717-05
3	New	S/N 0000037	Case Segment—Capture Cylinder, Lightweight P/N 1U52982-03
15	SRM-12B,23B;QM-6	S/N 0000010R3	Case Segment, Attach - Lightweight P/N 1U50716-08
6	DM-3,QM-3; SRM-5A,18B	S/N 0000007R4	Case Segment, Stiffener - Standard Weight P/N 1U50185-08
6	DM-3,QM-3; SRM-5A,18B	S/N 0000008R4	Case Segment, Stiffener - Standard Weight P/N 1U50185-08
4	DM-8	S/N 0000043R1	Case Segment, Aft Dome P/N 1U50129-11

Figure 4.2-1. Case Segment Reuse History--360H005A (LH motor)

	B RIGHT	Previous Use	Hydroproofs
Case Segment, Fwd Dome P/N 1U51473-03	S/N 0000025R3	SRM-14B,24A;QM-6	4
Case Segment, Cylinder P/N 1U50131-13	S/N 0000047R5	GTM-3; SRM-3A,12A, 23A;DM-8	6
Case Segment—Capture Cylinder, Std Weight P/N 1U52983-02	S/N 0000015	New	3
Case Segment, Cylinder Lightweight P/N 1U50717-05	S/N 0000058R2	SRM-12B,23B	4
Case Segment—Capture Cylinder, Lightweight P/N 1U52982-03	S/N 0000031	New	3
Case Segment, Cylinder Lightweight P/N 1U50717-05	S/N 0000015R4	DM-5;SRM-10A,20A; DM-8	6
Case Segment—Capture Cylinder, Lightweight P/N 1U52982-03	S/N 0000008R1	DM-8	4
Case Segment, Attach - Lightweight P/N 1U50716-08	S/N 0000013R3	SRM-14A,24A;QM-7	10
Case Segment, Stiffener - Standard Weight P/N 1U50185-08	S/N 0000013R3	GTM-3;SRM-9B,19B	5
Case Segment, Stiffener - Standard Weight P/N 1U50185-08	S/N 0000026R2	SRM-2A,11B	4
Case Segment, Aft Dome P/N 1U50129-11	S/N 0000033R2	SRM-22A;QM-6	6

Figure 4.2-2. Case Segment Reuse History--360H005B (RH motor)

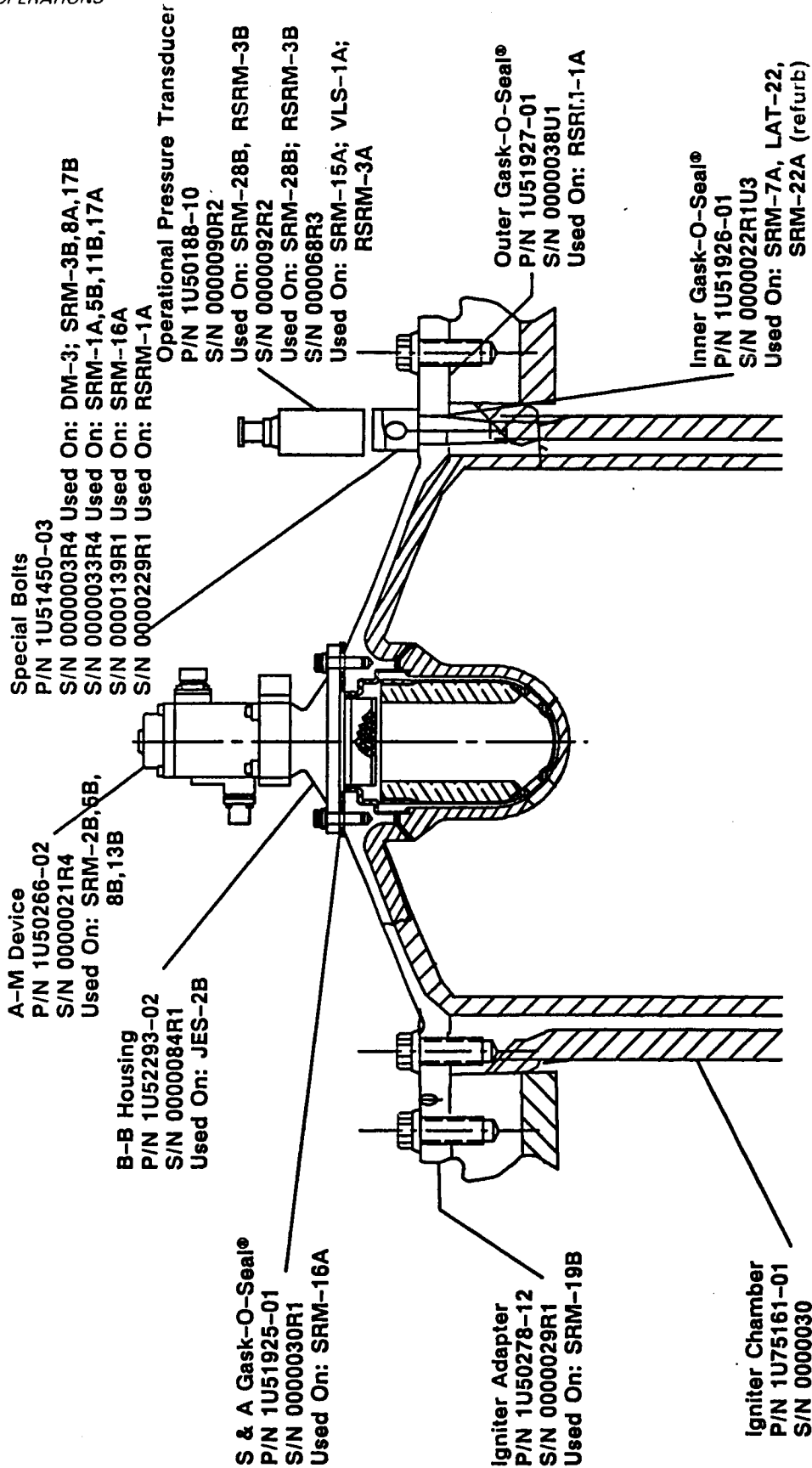
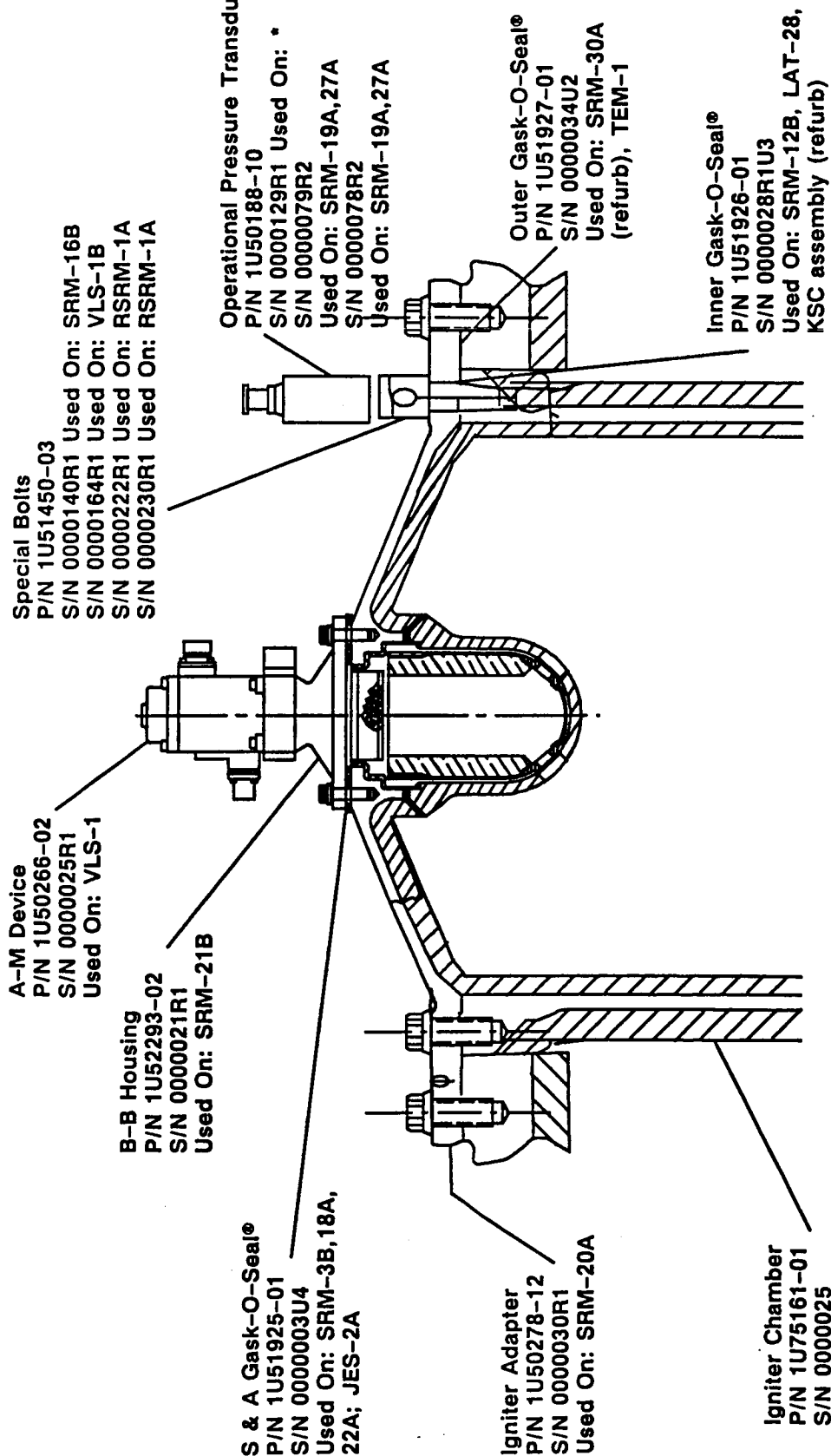


Figure 4.2-3. Previous Use History--LH Igniter

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*Returned to Thiokol and refurbished after being in stores at KSC

Figure 4.2-4. Previous Use History--RH Igniter

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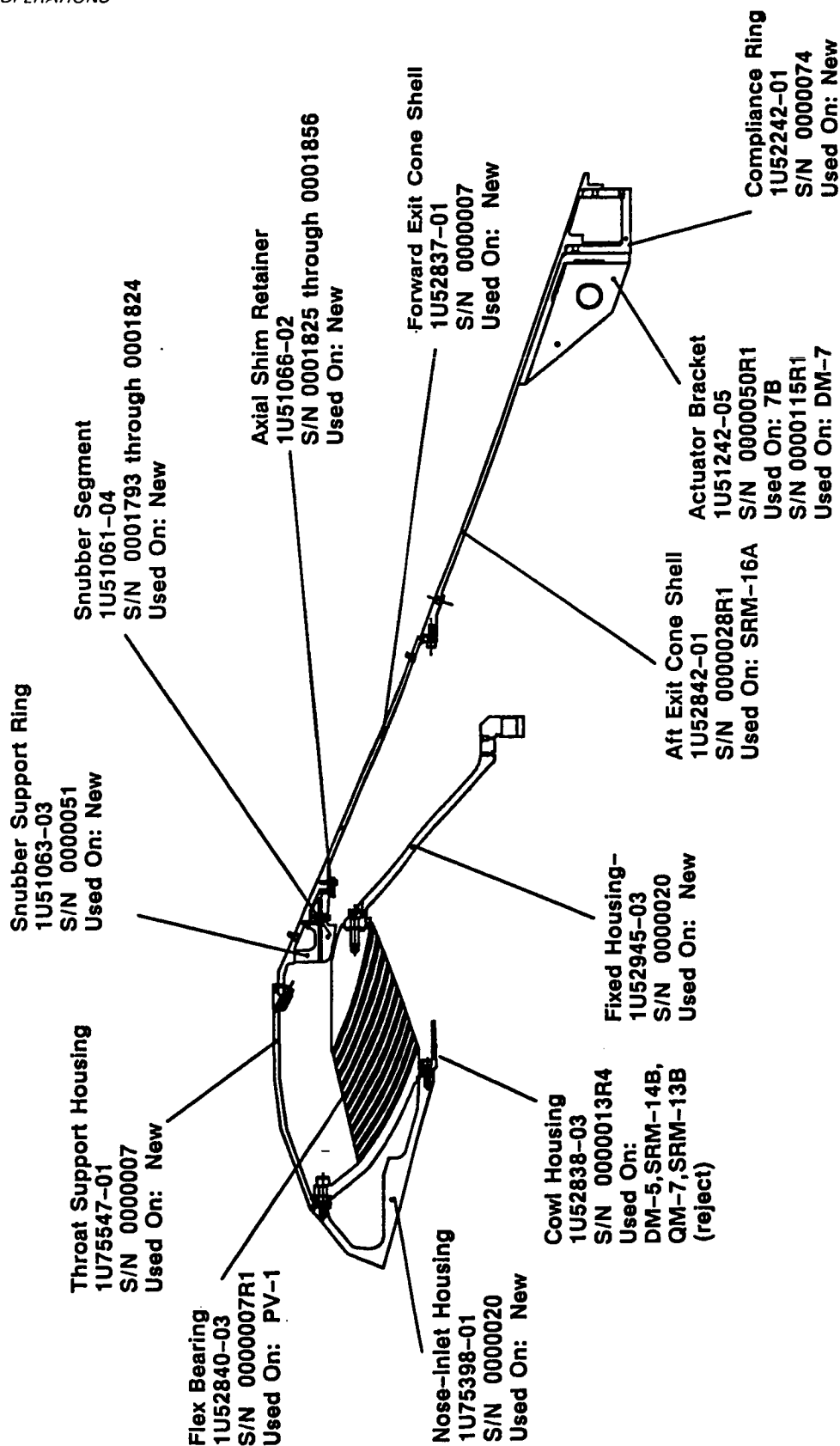


Figure 4.2-5. Previous Use History--LH Nozzle

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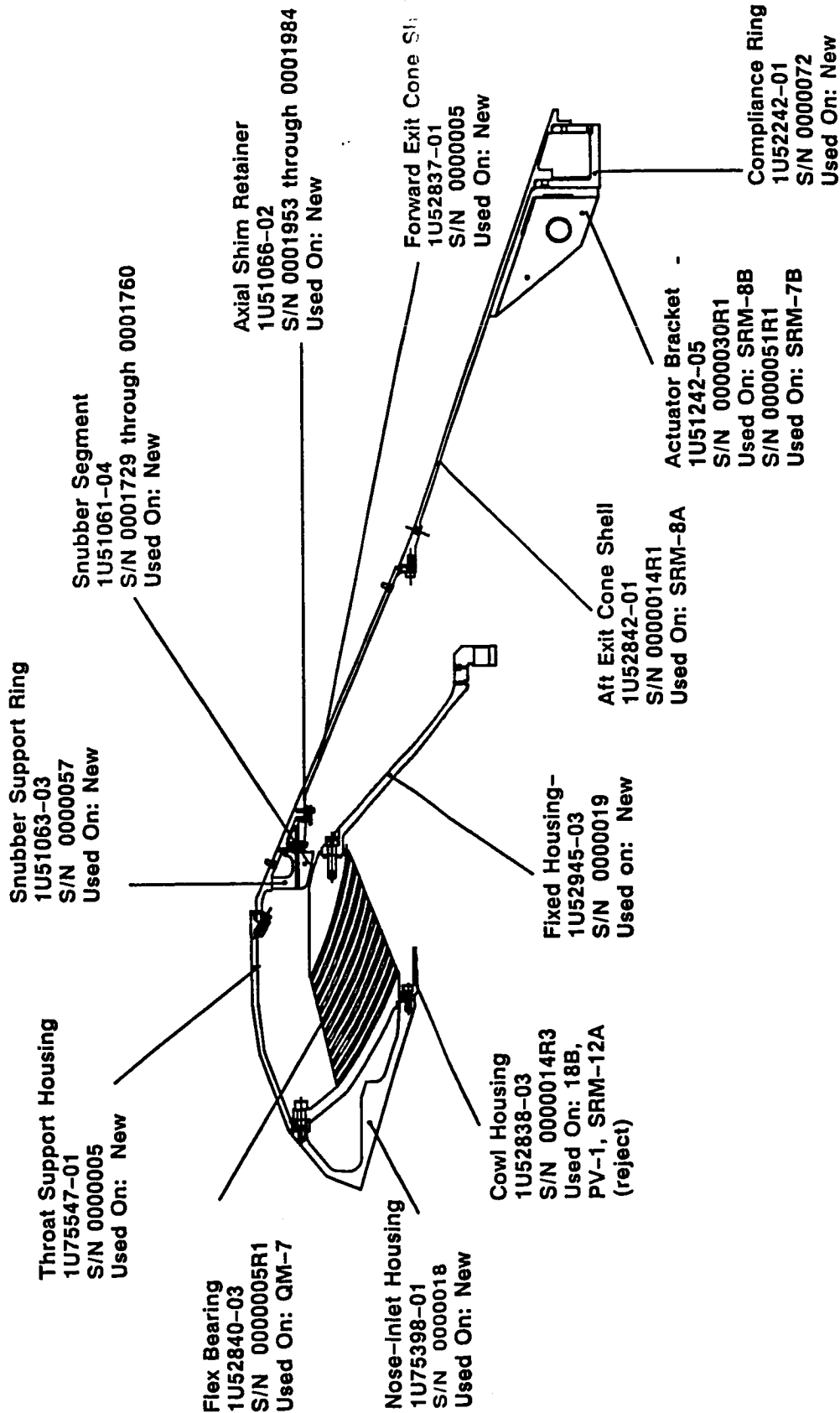


Figure 4.2-6. Previous Use History--RH Nozzle

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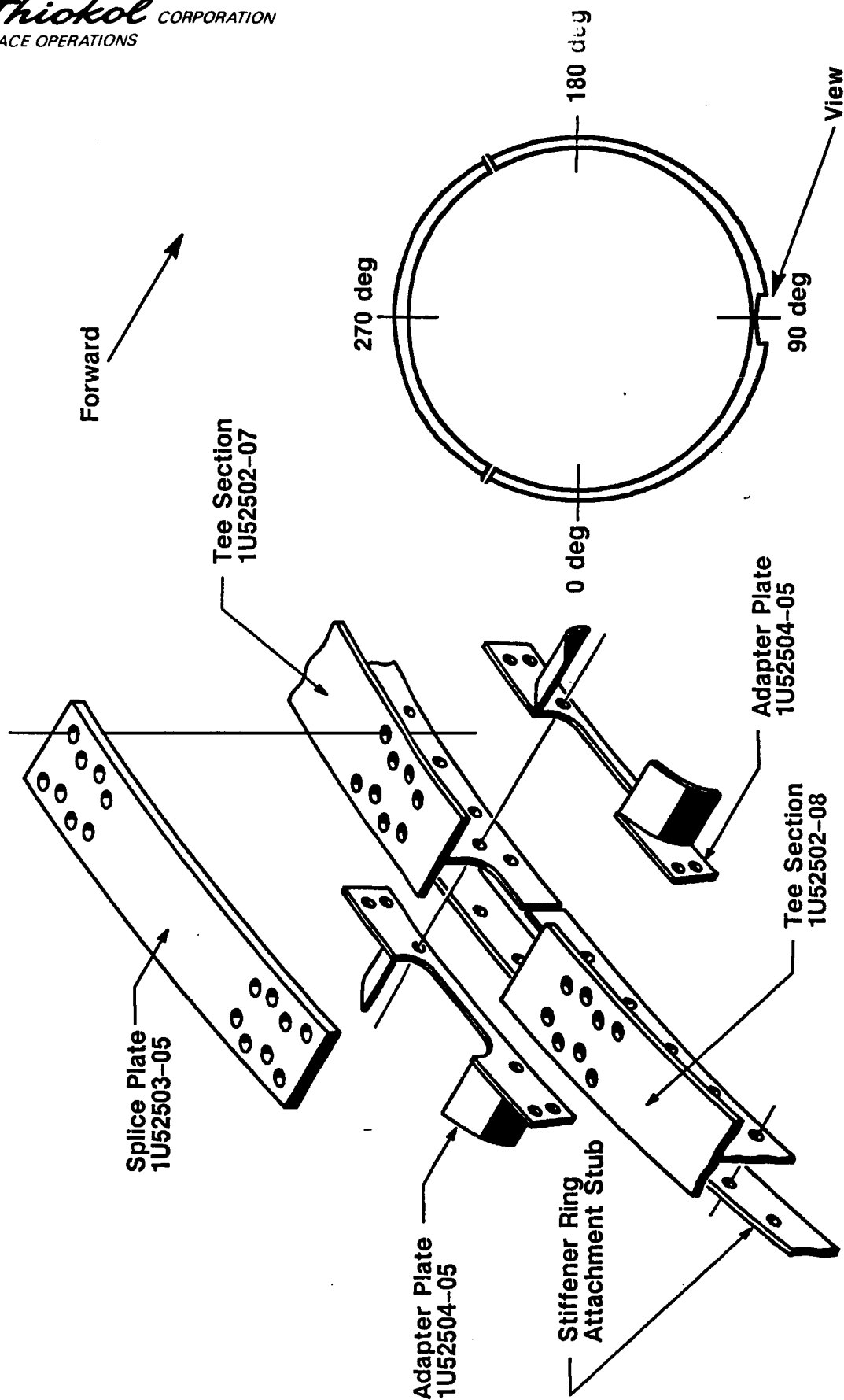


Figure 4.2-7. Previous Use History--Stiffener Rings (Part 1 of 2)

005-FRRa A303

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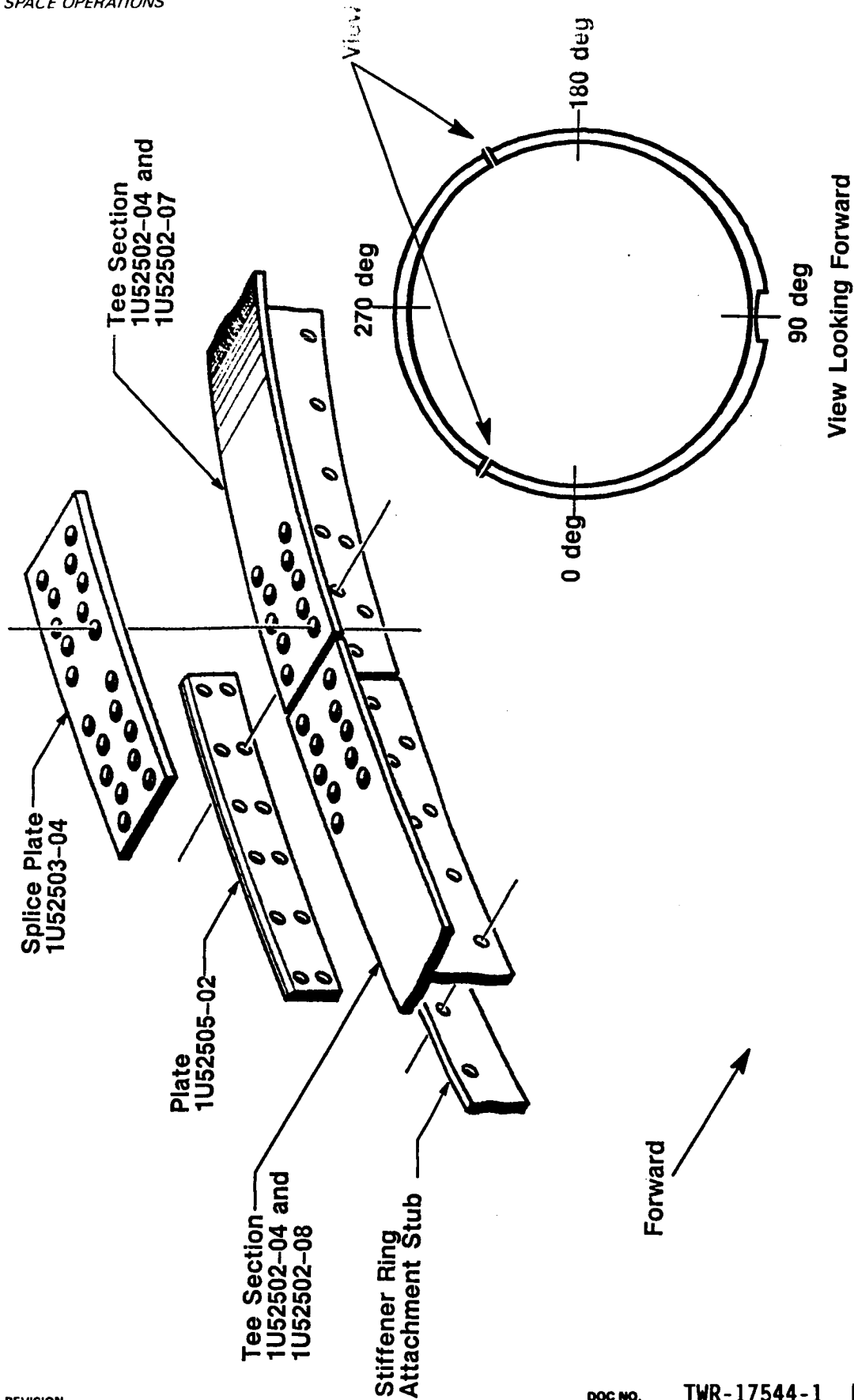


Figure 4.2-7. Previous Use History--Stiffener Rings (Part 2 of 2)

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SEC	PAGE	

Table 4.2-1. Previous Use History--Stiffener Rings

<u>Part No.</u>	<u>Serial No.</u>	<u>Previous Use</u>	<u>Part No.</u>	<u>Serial No.</u>	<u>Previous Use</u>
1U52502-04 Stiffener Ring	0000080R1	SRM-20	1U52503-05 Splice Plate	0000028	New
	0000084R1	SRM-22		0000029	New
	0000085R1	SRM-21		0000030	New
	0000087R1	QM-6		0000031	New
	0000088R1	QM-6		0000032	New
	0000089R1	QM-6		0000033	New
1U52502-07 Stiffener Ring	0000057	New	1U52504-05 Adapter Plate	0000153	New
	0000071	New		0000154	New
	0000085	New		0000155	New
	0000086	New		0000156	New
	0000087	New		0000157	New
	0000088	New		0000158	New
				0000159	New
				0000160	New
				0000161	New
				0000162	New
				0000163	New
				0000164	New
1U52502-08 Stiffener Ring	0000082	New	1U52505-02 Plate, Stiffener Ring	0000001R2	SRM-12, 21
	0000083	New		0000002R2	SRM-12, 21
	0000084	New		0000004R2	SRM-12, 21
	0000085	New		0000005R2	SRM-14, 22
	0000086	New		0000006R2	SRM-14, 22
	0000087	New		0000007R2	SRM-14, 22
				0000008R2	SRM-14, 22
				0000009R2	SRM-14, 22
				0000010R2	SRM-22
				0000105R1	SRM-22
				0000109R1	SRM-22
				0000110R1	SRM-22
1U52503-04 Splice Plate	0000001R2	SRM-12, 22			
	0000003R2	SRM-12, 22			
	0000004R2	SRM-12, 22			
	0000005R2	SRM-14, 22			
	0000006R2	SRM-14, 22			
	0000007R2	SRM-14, 22			
	0000008R2	SRM-14, 22			
	0000009R2	SRM-14, 22			
	0000010R2	SRM-14, 22			
	0000099R1	SRM-21			
	0000100R1	SRM-21			
	0000171	New			

4.2.2 Approved RSRM Changes and Hardware Changeouts

A summary of the changes made since 360T004 (STS-30) is given below. Complete descriptions of these changes are documented in Thiokol Corporation document TWR-19678 (Redesigned Solid Rocket Motor Flight Readiness Review--Level III)

Six Class I hardware changes since 360T004 (STS-30):

- a. K5NA cap removal over all field joint heater cables--ECP SRM-1861R1, increase cork dam thickness on forward segment.
- b. Igniter heater--ECP SRM-1921, igniter heater installed and checked out at Thiokol.
- c. Thermocouple wire exit locations were covered with K5NA and Hypalon paint--FEC RSRM-054R1, to seal wire location and prevent water entry in factory joint.
- d. Ambient temperature requirement for case acreage cork bonding operation lowered--ECP SRM-1959, sandpaper grit changed from fine to coarse grade.
- e. FEC RSRM-061R1--Cork covering pin retainer band trunnions and the joint heater system Kevlar[®] strap buckles on all field joints was removed and the area filled with K5NA to eliminate the possibility of voids under the cork. Relocate forward and aft Kevlar[®] strap buckles from 35 to 52 deg on the RH motor and 145 to 157 deg on the LH motor to eliminate the possibility of interference with tensioning tool and trunnions, valves and plugs.
- f. FEC RSRM-062--Apply PR1422 circumferentially to pin retainer band trunnions and heater egress areas only instead of full circumference on all field joints, thereby reducing use of PR1422 circumferentially to alleviate moisture seal positioning problems during Kevlar[®] band tensioning.

4.2.3 Critical Process and Operations and Maintenance Requirements and Specification Document (OMRSD) Changes

One critical process change:

Adhesive application thickness--OCR 137630. Changed adhesive application thickness at the throat inlet ring-to-metal housing interface. Reasoning: a) The 0.005-in. tolerance is not practical for adhesive application. b) Bondline thickness controlled by preplaced shims. c) Adhesive thickness 0.015 in. greater than shim thickness assures full contact of adhesive to phenolics. d) Excess adhesive is extruded from joint at ring application. e) Duplicates bonding practice used on other phenolic-to-phenolic interfaces.

Nine OMRSD changes:

- a. RCN MB8442AM--Reduced depth of allowable surface defect in the ET attach and stiffener stub holes.
- b. RCN MB8757M--Acceptance tests and reinspection required if S&A device is dropped.
- c. RCN MB8766A--Added new requirement to inspect igniter heater.
- d. RCN MB8804M--Revised acceptance criteria of raised metal in conical section of field joint vent port.
- e. RCN MB8845M--Deleted clevis insulation-to-case bond airload inspection.
- f. RCN MB8846A--Deleted KSC ambient temperature data gathering.
- g. RCN MB8847M--Provides for reverification of PMBT if launch delay occurs.
- h. RCN MB8867M--Removed PR1422 verifications.
- i. RCN MB8868M--Adds igniter heater inspection after functional test at KSC.

4.3 SRB MASS PROPERTIES (FEWG REPORT PARAGRAPH 2.2.0)

4.3.1 Sequential Mass Properties

Tables 4.3-1 and 4.3-2 provided 360H005 (STS-28) LH and RH motor reconstructed sequential mass properties, respectively.

4.3.2 Predicted Data Versus Postflight Reconstructed Data

Table 4.3-3 compares the LH half-weight RSRM (360H005A) predicted sequential weight and center of gravity (cg) data with the postflight reconstructed data. Table 4.3-4 compares the RH half-weight RSRM (360H005B) predicted sequential weight and cg data with the postflight reconstructed data. Actual 360H005 (STS-28) mass properties may be obtained from the Mass Properties History Log for Space Shuttle 360H005-LH (TWR-17342, dated 31 March 1989) and 360H005-RH (TWR-17343, dated 31 March 1989). Some of the mass properties data used have been taken from average actual data presented in the 5 March 1989 Mass Properties Quarterly Status Report (TWR-10211-90). Postflight reconstructed data reflect ballistics mass flow data from the 12.5-sample-per-second measured pressure traces and a predicted slag weight of 1,518 pounds. Those mass properties reported after separation reflect delta times previously used on earlier flights.

4.3.3 CEI Specification Requirements

Tables 4.3-5 and 4.3-6 present CEI specification requirements predicted and actual weight comparisons. Mass properties data for both RSRMs comply with the CEI specification requirements.

Table 4.3-1. Sequential Mass Properties of STS-28 LH SRM

EVENTS/TIMES	WEIGHT (LBS)	CENTER OF GRAVITY		MOMENT OF INERTIA		
		LONG.	LAT.	PITCH	ROLL	YAW
PRE-LAUNCH TIME = 0.00	1257193.5	1171.345	0.059	0.006	42463.407	880.239
LIFT-OFF TIME = 0.23	1256549.7	1171.472	0.059	0.006	42422.809	878.840
INTERMEDIATE BURN TIME = 20.00	1009316.3	1209.180	0.074	0.008	30481.950	758.567
INTERMEDIATE BURN TIME = 40.00	785015.7	1231.917	0.094	0.010	21439.505	621.879
MAX "Q" TIME = 54.00	653130.1	1228.991	0.113	0.012	17769.642	543.445
INTERMEDIATE BURN TIME = 60.00	596846.1	1226.219	0.123	0.013	16315.655	504.208
INTERMEDIATE BURN TIME = 80.00	400835.8	1214.688	0.181	0.019	11595.448	367.058
MAX "G" TIME = 87.00	336726.0	1215.293	0.215	0.023	10248.679	315.915
INTERMEDIATE BURN TIME = 100.00	231282.5	1232.615	0.310	0.033	8284.148	225.855
WEB BURN TIME = 108.49	174331.5	1267.194	0.410	0.044	7301.656	173.708
END OF ACTION TIME TIME = 120.54	144524.1	1315.108	0.493	0.053	6574.902	147.551
SEPARATION TIME = 123.68	143858.7	1317.029	0.495	0.053	6539.726	147.098
MAX REENTRY "Q" TIME = 318.68	143497.6	1316.854	0.496	0.053	6522.035	146.774
NOSE CAP DEPLOYMENT TIME = 348.68	143445.3	1316.835	0.496	0.053	6519.270	146.728
DROGUE CHUTE DEPLOYMENT TIME = 349.28	143444.3	1316.835	0.496	0.053	6519.215	146.727
FRUSTUM RELEASE TIME = 370.38	143407.5	1316.822	0.496	0.053	6517.258	146.694
MAIN CHUTE LINE STRETCH TIME = 371.68	143405.3	1316.821	0.496	0.053	6517.137	146.692
MAIN CHUTE 1ST DISREEFING TIME = 381.78	143387.7	1316.815	0.496	0.053	6516.197	146.677
MAIN CHUTE 2ND DISREEFING TIME = 387.68	143377.4	1316.812	0.496	0.053	6515.646	146.668
NOZZLE JETTISONED TIME = 388.38	141206.7	1306.825	0.495	0.053	6319.308	141.416
SPLASHDOWN TIME = 413.68	141104.7	1306.534	0.495	0.053	6311.482	141.310

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Table 4.3-2. Sequential Mass Properties of STS-28 RH SRM

EVENTS/TIMES	WEIGHT (LBS)	CENTER OF GRAVITY		MOMENT OF INERTIA		
		LONG.	LAT.	PITCH	ROLL	YAW
PRE-LAUNCH TIME = 0.00	1256697.7	1171.362	0.059	0.006	42474.476	879.875
LIFT-OFF TIME = 0.23	1256051.2	1171.487	0.059	0.006	42434.151	878.573
INTERMEDIATE BURN TIME = 20.00	1009654.2	1209.120	0.074	0.008	30526.172	758.707
INTERMEDIATE BURN TIME = 40.00	785621.6	1231.984	0.094	0.010	21476.537	622.101
MAX "Q" TIME = 54.00	653759.8	1229.125	0.112	0.012	17798.416	543.625
INTERMEDIATE BURN TIME = 60.00	597495.3	1226.369	0.123	0.013	16344.288	504.462
INTERMEDIATE BURN TIME = 80.00	400895.8	1214.845	0.181	0.019	11606.657	366.942
MAX "G" TIME = 87.00	336153.2	1215.506	0.215	0.023	10246.441	315.296
INTERMEDIATE BURN TIME = 100.00	230165.3	1233.307	0.312	0.033	8271.795	224.750
WEB BURN TIME = 107.93	176247.2	1265.836	0.406	0.043	7342.700	175.421
END OF ACTION TIME TIME = 120.76	144632.5	1315.357	0.492	0.053	6581.863	147.579
SEPARATION TIME = 123.68	143940.7	1317.248	0.495	0.053	6550.794	147.120
MAX REENTRY "Q" TIME = 318.68	143548.5	1317.211	0.496	0.052	6526.361	146.769
NOSE CAP DEPLOYMENT TIME = 348.68	143496.2	1317.192	0.496	0.052	6523.596	146.723
DROGUE CHUTE DEPLOYMENT TIME = 349.28	143495.2	1317.192	0.496	0.052	6523.541	146.722
FRUSTUM RELEASE TIME = 370.38	143458.4	1317.179	0.496	0.052	6521.584	146.690
MAIN CHUTE LINE STRETCH TIME = 371.68	143456.2	1317.178	0.496	0.052	6521.464	146.688
MAIN CHUTE 1ST DISREEFING TIME = 381.78	143438.6	1317.172	0.496	0.052	6520.524	146.672
MAIN CHUTE 2ND DISREEFING TIME = 387.68	143428.3	1317.169	0.496	0.052	6519.972	146.663
NOZZLE JETTISONED TIME = 388.38	141257.6	1307.190	0.495	0.052	6323.853	141.411
SPLASHDOWN TIME = 413.68	141155.6	1306.899	0.495	0.052	6316.032	141.305

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Table 4.3-3. Sequential Mass Properties--Predicted Versus Actual Comparisons for STS-28 LH SRM

Event	Weight (lb)				Longitudinal CG (in)			
	Predicted ¹	Actual	Delta	% Error	Predicted ¹	Actual	Delta	% Error
Pre-Ignition	1,257,193	1,257,193	0	0.00	1,171.345	1,171.345	0.000	0.00
Liftoff	1,256,558	1,256,549	-9	0.00	1,171.472	1,171.472	+0.000	0.05
Action Time	144,762	144,524	-238	0.16	1,314.514	1,315.108	+0.594	0.04
Separation ²	144,028	143,859	-169	0.12	1,316.490	1,317.029	+0.539	0.00
Nose Cap Deployment	143,445	143,445	0	0.00	1,316.844	1,316.835	-0.009	0.00
Drogue Chute Deployment	143,444	143,444	0	0.00	1,316.844	1,316.835	-0.009	0.00
Main Chute Line Stretch	143,405	143,405	0	0.00	1,316.830	1,316.821	-0.009	0.00
Main Chute 1st Distreefing	143,388	143,388	0	0.00	1,316.824	1,316.815	-0.009	0.00
Main Chute 2nd Distreefing	143,377	143,377	0	0.00	1,316.821	1,316.812	-0.009	0.00
Nozzle Jettison	141,148	141,207	59	0.04	1,306.553	1,306.825	+0.272	0.02
Splash Down	141,105	141,105	0	0.00	1,306.534	1,306.534	0.000	0.00

Notes:

1. Based on Mass Properties History Log Space Shuttle 360H005-LH, 31 March 1989 (TWR-17342).
2. The separation longitudinal center of gravity of 1,317.029 is 66.20% of the vehicle length.

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Table 4.3-4. Sequential Mass Properties--Predicted Versus Actual Comparisons for STS-28 RH SRM

Event	Weight (lb)			Longitudinal CG (in)		
	Predicted ¹	Actual	Delta	% Error	Predicted ¹	Actual
Pre-Ignition	1,256,698	1,256,698	0	0.00	1,171.362	1,171.362
Liftoff	1,256,062	1,256,051	-11	0.00	1,171.494	1,171.487
Action Time	144,812	144,633	-179	0.12	1,314.914	1,315.357
Separation ²	144,078	143,941	-137	0.10	1,316.891	1,317.248
Nose Cap Deployment	143,496	143,496	0	0.00	1,317.247	1,317.192
Drogue Chute Deployment	143,495	143,495	0	0.00	1,317.247	1,317.192
Main Chute Line Stretch	143,456	143,456	0	0.00	1,317.233	1,317.178
Main Chute 1st Disreefing	143,438	143,439	1	0.00	1,317.227	1,317.172
Main Chute 2nd Disreefing	143,428	143,428	0	0.00	1,317.224	1,317.169
Nozzle Jettison	141,199	141,258	59	0.04	1,306.974	1,307.190
Splash Down	141,156	141,156	0	0.00	1,306.955	1,306.899

Notes:

1. Based on Mass Properties History Log Space Shuttle 360H005-RH, 31 March 1989 (TWR-17343).
2. The separation longitudinal center of gravity of 1,317.248 is 66.21% of the vehicle length.

Table 4.3-5. Predicted Versus Actual Weight (lb) Comparisons for STS-28 LH SRM

Item	Minimum	Maximum	Predicted ³	Actual	Delta	% Error	Notes
Inerts							
Prefire, Controlled		151,975	150,191	150,191	0	0.00	1
Propellant	1,103,560		1,107,002	1,107,002	0	0.00	1
Usable			1,106,143	1,106,380	+237	0.02	2
To Liftoff			535	543	+8	1.47	
Liftoff to Action			1,105,608	1,105,837	+229	0.02	2
Unusable,			859	622	-237	38.10	
Action to Separation			669	600	-69	11.50	
After Separation			190	22	-168	763.64	
Slag			1,518	1,518	0	0.00	2

Notes:

1. Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI Specification).
2. Slag included in usable propellant, liftoff to action.
3. Based on 31 March 1989, Mass Properties History Log Space Shuttle 360H005-LH (TWR-17345).

Table 4.3-6. Predicted Versus Actual Weight (lb) Comparisons for STS-28 RH SRM

Item	Minimum	Maximum	Predicted ³	Actual	Delta	% Error	Notes
Inerts							
Prefire, Controlled		151,975	150,247	150,247	0	0.00	1
Propellant	1,103,560		1,106,450	1,106,450	0	0.00	1
Usable			1,105,592	1,105,772	+180	0.02	2
To Liftoff			535	546	+11	2.01	
Liftoff to Action			1,105,057	1,105,226	+169	0.02	2
Unusable			859	679	-180	26.51	
Action to Separation			669	626	-43	6.87	
After Separation			190	53	-137	258.49	
Slag			1,518	1,518	0	0.00	2

Notes:

1. Requirement per CPWL-3600A, Addendum G, Part I, (RSRM CEI Specification).
2. Slag included in usable propellant, liftoff to action.
3. Based on 31 March 1989, Mass Properties History Log Space Shuttle (TWR-17343).

4.4 RSRM PROPULSION PERFORMANCE (FEWG REPORT PARAGRAPH 2.3.0)

4.4.1 High-Performance Motor Versus RSRM Performance Comparisons

The reconstructed thrust-time traces of flight motor set 360H005 at standard conditions were averaged with the high-performance motor (HPM)/RSRM population and compared to the CEI specification limits. The results are shown in Figure 4.4-1.

4.4.2 SRM Propulsion Performance Comparisons

The reconstructed RSRM propulsion performance is compared to the predicted performance in Table 4.4-1. The following comments are to explain the table values. The RSRM ignition interval is to be between 202 and 302 ms after ignition command to the NASA standard initiator in the S&A device. The ignition interval ends when the headend chamber pressure has increased to a value of 563.5 psia. The maximum rate of headend chamber pressure buildup during the ignition transient is required to be less than 115.9 psia for any 10-ms interval. However, no high sample rate ignition data were available for this flight (due to the elimination of DFI). Therefore, no rise rate or ignition interval is reported.

Separation is based upon the 50-psia cue from the last RSRM, plus 4.9 sec, plus a time delay between the receipt and execution of the command to separate. No time delay is assumed in the prediction. The decay time intervals are measured from the time motor headend chamber pressure has decayed to 59.4 psia to the time corresponding to 85,000 lb of thrust.

4.4.3 Matched Pair Thrust Differential

Table 4.4-2 shows that thrust differential during steady state and tailoff. All the thrust differential values were near the nominal values experienced by previous flight SRMs and were well within the CEI specification limits. The thrust values used for the assessment were reconstructed at the delivered conditions of each motor.

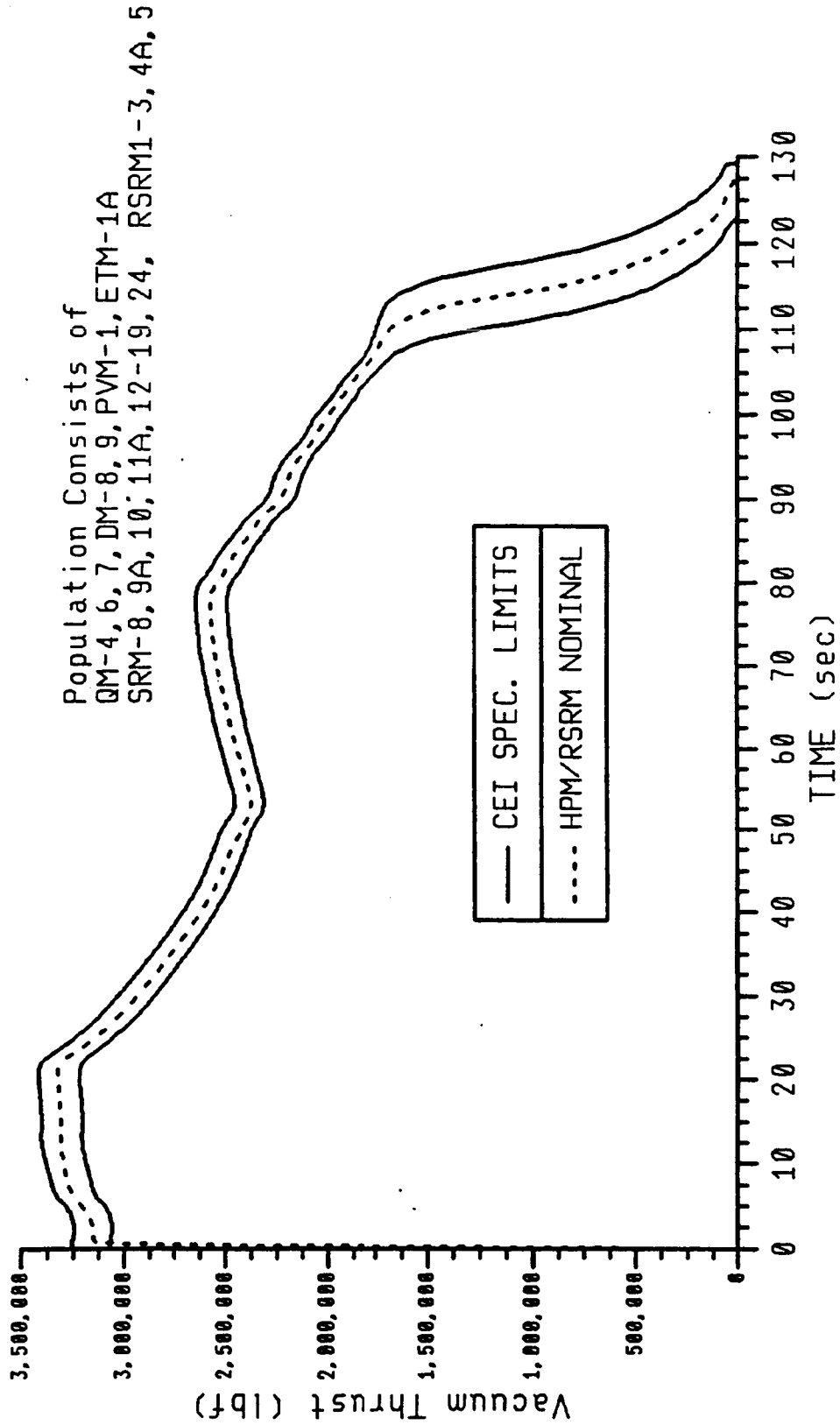


Figure 4.4-1. HPM/RSRM Nominal Thrust Versus CEI Specification

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Table 4.4-1. RSRM Propulsion Performance Assessment

	LH Motor (82°F)		RH Motor (82°F)	
	<u>Predicted</u>	<u>Actual</u>	<u>Predicted</u>	<u>Actual</u>
Impulse Gates				
I-20 (10 ⁶ lbf-sec)	66.88	66.69	66.85	65.57
I-60 (10 ⁶ lbf-sec)	177.57	177.20	177.47	177.14
I-AT (10 ⁶ lbf-sec)	296.83	297.00	296.69	297.27
Vacuum I _{sp} (lbf*sec lbm)	268.3	268.4	268.3	268.8
Burn Rate (in./sec) (at 60°F)	0.370	0.369	0.370	0.369
Event Times (sec)*				
Ignition Interval	0.232	NA	0.232	NA
Web Time*	107.8	108.5	107.8	107.9
Action Time*	119.8	120.5	119.8	120.8
Separation Command (sec)	122.6	122.9	122.6	123.7
PMBT (°F)	82.0	82.0	82.0	82.0
Maximum Ignition Rise Rate (psia 10 ms)	91.9	NA	91.9	NA
Decay Time (sec) (59.4 psia to 85 K)	2.9	3.4	2.9	2.9
Tailoff Imbalance	<u>Predicted</u>	<u>Actual</u>		
Impulse Differential (klbf-sec)	-36	+390		

Note: Impulse Imbalance = LH SRM—RH SRM

*All times are referenced to ignition command time except where noted by an *. These times are referenced to lift-off time (ignition interval)

Table 4.4-2. RSRM Thrust Imbalance Assessment

<u>Event</u>	<u>Imbalance Specification (klbf)</u>	<u>Maximum Imbalance (klbf)</u>	<u>Time of Maximum Imbalance (sec)</u>
Steady State (1.0 sec to first web time minus 4.5 sec, 1bf, 4 sec average)	85	-38.1	85.0
Transition (first web time minus 4.5 sec to first web time, 1bf)	85-268 Linear	-26.1	107.5
Tailoff (first web time to last action time)	710	+137.6	111.0

Note: Thrust Imbalance = LH SRM—RH SRM

4.4.4 Performance Tolerances

A comparison of the LH and RH motor calculated and reconstructed parameters at a PMBT of 60°F with respect to the nominal values and the SRM CEI specification maximum 3-sigma requirements is given in Table 4.4-3.

4.4.5 Igniter Performance

Due to the elimination of DFI, no evaluation of the igniter performance is possible. Also, no evaluation of the ignition interval, pressure rise rate, and ignition thrust imbalance requirements is possible.

4.5 RSRM NOZZLE THRUST VECTOR CONTROL PERFORMANCE (FEWG PARAGRAPH 2.4.3)

No RSRM nozzle thrust vector control (TVC) torque calculations for motor set 360H005 were possible due to DFI elimination. This section is reserved pending the availability of DFI on future flights. The nozzle char and erosion performance is discussed in Section 4.11.4 of this volume and Volume V of this report.

Table 4.4-3. RSRM Performance Comparisons

Parameter	SRM CEI (+/-) Max 3-sigma Variation (%)	Nominal Value*	LH RSRM		RH RSRM	
			360H005A (60°F)	360H005A Variation (%)**	360H005B (60°F)	360H005B Variation (%)**
Web Time (sec)	5.0	111.7	110.9	-0.72	110.6	-0.98
Action Time (sec)	6.5	123.4	123.3	-0.08	123.7	+0.24
Web Time Avg Pressure (psia)	5.3	660.8	665.6	+0.73	668.4	+1.15
Max Headend Pressure (psia)	6.5	918.4	923	+0.50	923	+0.50
Max Sea Level Thrust (mlbf)	6.2	3.06	3.09	+0.98	3.08	+0.65
Web Time Avg Vac Thrust (mlbf)	5.3	2.59	2.61	+0.77	2.61	+0.77
Vac Del Specific Impulse (lbf*sec/lbm)	0.7	267.1	268.1	+0.37	268.5	+0.52
Web Time Vac Total Impulse (mlbf*sec)	1.0	288.9	289.1	+0.07	289.1	+0.07
Action Time Vac Total Impulse (mlbf*sec)	1.0	296.3	296.6	+0.10	297.0	+0.24

*QM-4 static test and SRM-8A and B, SRM-9A, SRM-10A and B, SRM-11A, SRM-13A and B Flight average at standard conditions

**Variation = $((\text{RSRM 5A} - \text{nominal}) / \text{nominal}) * 100$
 $((\text{RSRM 5B} - \text{nominal}) / \text{nominal}) * 100$

4.6 RSRM ASCENT LOADS—STRUCTURAL ASSESSMENT (FEWG REPORT PARAGRAPH 2.5.2)

Motor set 360H005 did not have any DFI installed to evaluate the motor structural performance. This section is reserved pending any future motors that incorporate DFI.

4.7 RSRM STRUCTURAL DYNAMICS (FEWG REPORT PARAGRAPH 2.6.2)

No accelerometer data were available due to the elimination of DFI on flight set 360H005. This section is reserved pending the installation of accelerometers on future flight motors.

4.8 RSRM TEMPERATURE AND TPS PERFORMANCE (FEWG REPORT PARAGRAPH 2.8.2)

4.8.1 Introduction

This section documents the thermal performance of the 360H005 (STS-28R) SRM external components and TPS as determined by postflight hardware inspection. Assessments of debris, mean bulk temperature predictions, on-pad ambient/local induced environments, LCC, and GEI/joint heater sensor data are also included. Performance of SRM internal components (insulation, case components, seals, and nozzles) is reported in Section 4.11 of this volume.

4.8.2 Summary

4.8.2.1 Postflight Hardware Inspection. Postflight inspection revealed no unexpected problems due to flight heating environments. The condition of both SRMs was similar to that of previous flight motors. A complete external heating evaluation of postflight hardware is given in Section 4.8.3.1 of this volume. Nozzle erosion is discussed in Section 4.11.4 of this volume.

4.8.2.2 Debris Assessment. The NSTS debris criteria for missing TPS were not violated. A complete SRM debris assessment is given in Section 4.8.3.2 of this volume. Highlights are discussed as follows.

Missing TPS cork pieces were generally less than the established criteria of 0.70 in.³ and were all caused by nozzle severance debris and/or splashdown loads and debris.

All GEI measurement stimulation identification number (MSID) labels forward of the ET attach ring were removed prior to launch because of debris concern raised during the STS-30R postflight inspection. Most of the remaining labels on the aft segment of STS-28R were lost during flight, but are not considered a debris issue because they are located aft of the orbiter. The epoxy closeouts over these labels, generally up to 1/8 in. thick, have been a questionable debris concern; action is underway to use stencils instead of labels on future flights.

4.8.2.3 Mean Bulk Temperature Predictions. Temperature predictions were made at different timeframes during the countdown. A discussion of these predictions is presented in Section 4.8.3.3 of this volume. Final postflight

predictions from reconstructed data are: 1) the PMBT was 82°F and 2) The flex bearing mean bulk temperature (FBMBT) was 82°F.

4.8.2.4 On-Pad Environment Evaluations. A complete environment evaluation is given in Section 4.8.3.4. A summary of key observations follows.

Ambient Conditions. Ambient temperature data recorded during the 78-hr period prior to launch varied from 73° to 94°F. The normal temperature range experienced during the month of August is from a low of 74°F to a high of 86°F. The 94°F temperature represents a +3 σ deviation from the historical August mean afternoon (1200 to 1400 hr) high temperature. The windspeeds during this same timeframe were near historical conditions.

SRM Local. The local on-pad prelaunch environment resulting from August historical predictions suggests as much as a 1°F temperature suppression while the ET is loaded for winds from the southeast direction. The actual wind direction during the LCC timeframe oscillated from the south to the west. From GEI assessments, there was evidence of minor temperature suppression (2° to 3°F inboard of the RH SRB) due to ET cooling effects.

4.8.2.5 Launch Commit Criteria. No LCC thermal violations occurred. Measured GEI and heater sensor data, as compared to the LCC requirements, are discussed in Section 4.8.3.5 of this volume. Highlights of heating operations are summarized as follows.

The igniter heaters were activated for approximately 20 hr and performed as expected. Cooldown after heater shutoff occurred over an approximate 8-hr period and resulted at T-5 min in igniter sensor temperature of 83°F. These 83°F temperatures were only 1°F higher than the preactivation temperatures.

The six field joint heaters performed adequately and as expected, with an 11°F sensor temperature range from 92° to 103°F, during the LCC timeframe. All 24 field joint sensors recorded temperatures in the expected range. Two and a half weeks prior to launch the minimum field joint LCC redline was reduced from 85° to 68°F. This modification was a change unique to STS-28R and was a precaution taken in the event of a primary heater failure on the LH forward field joint. (The redundant LH forward field joint heater failed the DWV test.)

The SRB aft skirt purge operation was not activated until T-15 min because of the warm ambient and component temperatures. This activation was done in accordance with the operations maintenance instructions (OMI) which instructs the operator to control the "SRB Flow Rate Purge" as required to maintain the following limits: 1) flex bearing at 60° to 115°F and 2) case-to-nozzle joint at 75° to 115°F.

4.8.2.6 Prelaunch Thermal Data Evaluation.

Infrared Temperature Measurements. IR temperature measurements from both the IR gun and the STI were compared with GEI. A complete evaluation is found in Section 4.8.3.6 of this volume. Highlights are summarized as follows.

The IR measurements taken by the IR gun during the T-3 hr ice/debris team pad inspection were found to be anomalous and therefore not reported. The STI temperature measurements were used along with the GEI measurements to monitor SRM surface temperatures. Temperatures varied between 76° and 80°F during the T-3 hr pad inspection for both STI and GEI temperatures.

4.8.3 Results Discussion

4.8.3.1 Postflight Hardware Inspection. Following the recovery of the STS-28R SRBs, a postflight inspection of the external hardware was conducted at the SRB Disassembly Facility (Hanger AF). The TPS performance was considered to be excellent in all areas, with external heating effects less than predicted (Table 4.8-1). Predictions due to the worst-case design trajectory environments (Table 4.8-2) will be documented in the SRB Thermal Design Data Book, SE-019-068-2H.

The condition of both motors appeared to be similar to previous flight motors, with most of the heat effects seen on the aft segments on the inboard sides of the SRBs. The aft segment inboard regions facing the ET experience high aerodynamic heating normal to protuberance components as well as the highest radiant heating of aft-facing surfaces (factory joints, stiffener rings, and stubs). In this area there was slight ablation of the TPS over the factory joints, the stiffener rings and stubs, and GEI cabling runs. A concise summary of the external hardware condition is listed in Table 4.8-3.

Field Joints. All field joints on both motors were in excellent condition. There were no signs of ablation on any one of the joint protection systems (JPS), with only slight paint blistering on the cork cover. The paint on the K5NA closeout aft of the cork was also slightly darkened and blistered, with occasional pitting. This was probably due to water impact. The K5NA closeouts over the pin retainer band trunnion performed well, as expected. However, there was a 2.5-in. crack on one of the closeouts on the RH motor aft field joint.

Factory Joints. The factory joints on each of the motors were in very good condition. The only signs of ablation experienced on the factory joints were located on the aft segments of each motor. There was only slight ablation or charring that occurred between approximately 220 and 320 deg circumferentially on each motor. Again, this is a normal occurrence that has been observed on previous flight motors. The weatherseal over the forward center factory joint of the LH SRB had a 6-in. unbond at approximately the 0-deg location and a partial 2-in. unbond at the 5-deg location. There was also a 2-in. partial unbond on the LH forward center weatherseal at the 50-deg location.

Systems Tunnel. The cork TPS adjacent to the systems tunnel floorplate was in excellent condition. There was very little paint discoloration and no measurable cork ablation.

Stiffener Rings. The stiffener ring TPS was generally in very good condition with only slight thermal degradation. The ablation was again experienced in the 220- to 320-deg sector, with ethylene-propylene-diene monomer (EPDM) on the outer flange showing heat effects. This region was subjected to aeroheating along the outboard tip forward face, while the aft experienced radiant heating. The K5NA TPS on the forward side of the stubs was also slightly charred in the same regions, with intermittent pitting around the whole circumference. The forward stiffener ring on the RH SRB was slightly fractured during water impact near the 100-deg location.

GEI Cables. The cork and K5NA TPS covering the GEI and cableways was generally in good condition. Very little heat effect was observed, with only slight paint discoloration and blistering. These were only minor cork

losses, with all being attributed to debris impact during reentry or at splashdown. The largest missing cork piece, was a 10- by 2-in. section at Station 1751 on the RH SRB. All other missing sections were less than 3 in. wide or long. The K5NA closeouts between the cork runs performed very well with no material loss.

Nozzle. The external appearance of the nozzles was similar to that of other flights. The carbon-cloth phenolic (CCP) on the exit cone was either fractured or completely missing by actions resulting from the LSC and the water impact. The aluminum shell showed no sign of heat damage. The internal parts of both nozzles had the appearance of previous postflight hardware. There were intermittent impact marks located circumferentially around both of the nozzles. There were a few instances of charred CCP popping up and postfire wedgeouts which have been observed on previous postfire nozzle inspections.

Table 4.8-1. STS-28R RSRM External TPS (erosion) Performance Summary—Both Motors

<u>Component</u>	<u>TPS Material</u>	<u>Maximum Erosion (in.)</u>	
		<u>Predicted</u>	<u>Measured</u>
Field Joints	Cork	0.003	None
Factory Joints	EPDM	0.014	Not measurable*
Systems Tunnel	Cork	0.014	None
Stiffener Rings	EPDM	0.009	Not measurable*
GEI Closeout	Cork	0.036	Not measurable*
Nozzle Exit Cone	Cork	0.104	NA**

*All evidences of minor erosion were apparent only on the inboard region of the aft segment, where the flight-induced thermal environments are the most severe.

**Nozzle exit cones are not recovered.

Table 4.8-2. SRB Flight-Induced Thermal Environments

<u>Thermal Environment</u>	<u>Related Document</u>
Ascent Heating	Document No. STS 84-0575, dated 24 May 1985 Change Notice 2, SE-698-D, dated 30 Apr 1987 Data on computer tapes No. DN 4044 and DN 9068 Change Notice 3, SE-698-D, dated 30 Oct 1987; tape No. 5309
Base Recirculation Heating	Document No. STS 84-0259, dated October 1984 Change Notice 1, SE-698-D, dated 30 Sep 1987
SSME and SRB Plume Radiation	Document No. STS 84-0259, dated October 1984 Change Notice 1, SE-698-D, dated 30 Sep 1987
SSME Plume Impingement SRB Separation	Document No. STS 84-0259, dated October 1984 Change Notice No. 1, SE-698-D, dated 30 Sep 1987
Reentry Heating	Document No. SE-0119-053-2H, Rev D, dated August 1984, and Rev E, dated 12 Nov 1985

Table 4.8-3. STS-28R RSRM External Hardware Performance
Summary—Both Motors

<u>Component</u>	<u>TPS Material</u>	<u>Performance</u>	<u>Recovered Hardware Performance Assessment</u>
Field Joints	Cork	Typical	All field joints in excellent condition; slight paint blistering; 2.5-in. crack in RH aft field joint K5NA trunnion closeout
Factory Joints	EPDM	Typical	All factory joints in very good condition; slight ablation of EPDM on aft segment joints on inboard side of both motors (approximately 220 to 320 deg); 6-in. unbond on LH forward weatherseal at 0 deg, 2-in. partial unbond at 50 deg; 2-in. partial unbond on LH forward center weatherseal at 30 deg
Systems Tunnel	Cork	Typical	Cork TPS adjacent to tunnel floorplate in excellent condition; very little paint discoloration and no measurable cork ablation
Stiffener Rings	EPDM	Typical	Normal thermally, only significant ablation on stub tips and leading edge of T-sections on inboard side of motors; forward stiffener ring on RH motor was slightly damaged at approximately 100 deg due to water impact
GEI, Cables	Cork K5NA	Typical	Generally in good condition, with slight paint blistering; some small areas of cork missing on GEI cable runs due to nozzle severance debris on water impact
Motor Case	NA	Typical	No hot spots or discoloration of motor case paint due to external or internal heating; aft segments extensively sooted

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4.8.3.2 Debris Assessment. The NSTS debris criteria for missing TPS were not violated. The TPS cork pieces that were missing were generally less than the established criteria of 0.70 in.³ and were all caused by nozzle severance debris or by water impact. All GEI MSID labels forward of the ET attach ring were removed prior to launch because of debris concerns raised during STS-28R were lost during flight, but are not considered a debris issue because they are located aft of the orbiter.

Based on the quick-look external inspection, the SRM TPS performed adequately on STS-28R. The problem of losing TPS cork caps covering the instrumentation cables (a result of poor cork bonds) appears to have been corrected. The K5NA closeouts performed well as expected and provided the necessary thermal protection to the cables which have a temperature limit of 500°F.

4.8.3.3 PMBT and FBMBT Predictions. Temperature predictions (°F) were performed at various times with respect to the launch of STS-28R. They are predicted for the time of launch and are summarized as:

	<u>Historical</u>	<u>L-9 Days</u> <u>7-30-89</u>	<u>L-2 Days</u> <u>8-6-89</u>	<u>L-24 Hr</u> <u>8-7-89</u>	<u>Post</u>
PMBT	78	82	82	--	82
FBMBT	80	84	--	86	82

As can be seen, PMBT did not change from the L-9 days prediction to the postlaunch calculation using reconstructed ambient data.

All predictions were based on the following four sources of data.

1. Thiokol Launch Support Services (LSS) office/Hoyt Sherard, faxed weather data
2. KSC Weather Station/Russ Bolten, modem transmission
3. Florida Solar Energy Center (FSEC), modem transmission
4. Contract Databasing Service (CDS) data collected at HOSC, faxed weather data

The data from Hoyt Sherard were used, wherever possible, as the primary source of environmental data. The ambient temperature from Russ Bolton was used as the next source along with windspeed and direction from the FSEC. The ambient temperature data from the FSEC were used as the last resource.

The FSEC, however, was the sole source for sky temperature and solar flux. The CDS data collected at the HOSC during the countdown were the ambient temperature data used during the 37 hr prior to launch.

The FMBT predictions and the postlaunch calculation changed due to two factors. First, the average ambient temperature for the 3 days prior to launch was 3.1°F warmer than normal (82.5°F versus 79°F) resulting in an prepurge FMBT of 82°F. And second, the aft skirt purge was not operated as had been expected (15 min versus 16 hr). Both the T-9 day and T-24 hr predictions were based on the assumption that a 16-hr purge would increase the FMBT by 4°F.

4.8.3.4 On-Pad Environmental Evaluations. Actual environmental data for the final 24 hr prior to launch can be visualized in Figures 4.8-1 through 4.8-5 and summarized together with GEI in Table 4.8-4. The ambient temperature data recorded during a 78-hr period prior to launch varied from 73° to 94°F. The normal temperature range experienced during the month of August is from a low of 74°F to a high of 86°F. The 94°F temperature represents a +3 σ deviation from the historical August mean afternoon (1200 to 1400 hr) high temperature. Windspeeds during this same timeframe were similar to historical conditions.

The local on-pad prelaunch environment resulting from August historical predictions suggest as much as a 1°F temperature suppression while the ET is loaded for winds from the southeast direction. The actual wind direction during the LCC timeframe oscillated from the south to the west. From GEI assessments, there was evidence of minor temperature suppression (2° to 3°F inboard on the RH SRB) due to ET cooling effects.

The chilling effect developed from L-1.5 hr up until the time of launch and occurred at the 270-deg case LCC sensor locations on the RH SRB. This determination was made by first noting that the temperatures on the RH and LH motors at these three locations were identical when the ET was empty. Next, temperature comparisons were made, at various points in time during the countdown, to determine the temperature difference between the five LCC inboard sensors on the RH motor versus those on LH motor. It was seen that

four of the five sensors on the RH motor, at this angular location, dropped 2.0° to 4.0°F lower than the corresponding sensor temperatures on the LH motor. The average cooling effect, using all five case acreage LCC sensors on both motors, is 2.6°F. This assumes that no cooling occurred on the LH motor at the 270-deg location. If cooling did occur at this location on the LH motor, a determination which could not be made, then the net cooling effect would be even greater.

It should also be mentioned that the gaseous oxygen (GOX) venting may have played a small part in this RH motor inboard location cooling occurrence. It was noted that GOX vapors were blown toward the motors at various times during the countdown.

From the cooling which occurred on this flight set and from that which occurred on STS-29R and STS-30R, a general conclusion can be made. That conclusion is that a consistent wind from the east will cause cooling on the inboard side of the west (LH) motor and a consistent wind from the west will cause cooling on the inboard side of the east (RH) motor. This occurrence is a consequence of air cooling as it is blown around the ET, resulting in regions of subcooling at inboard locations. (The wind direction for STS-28R during the last hour prior to launch was principally from the west.)

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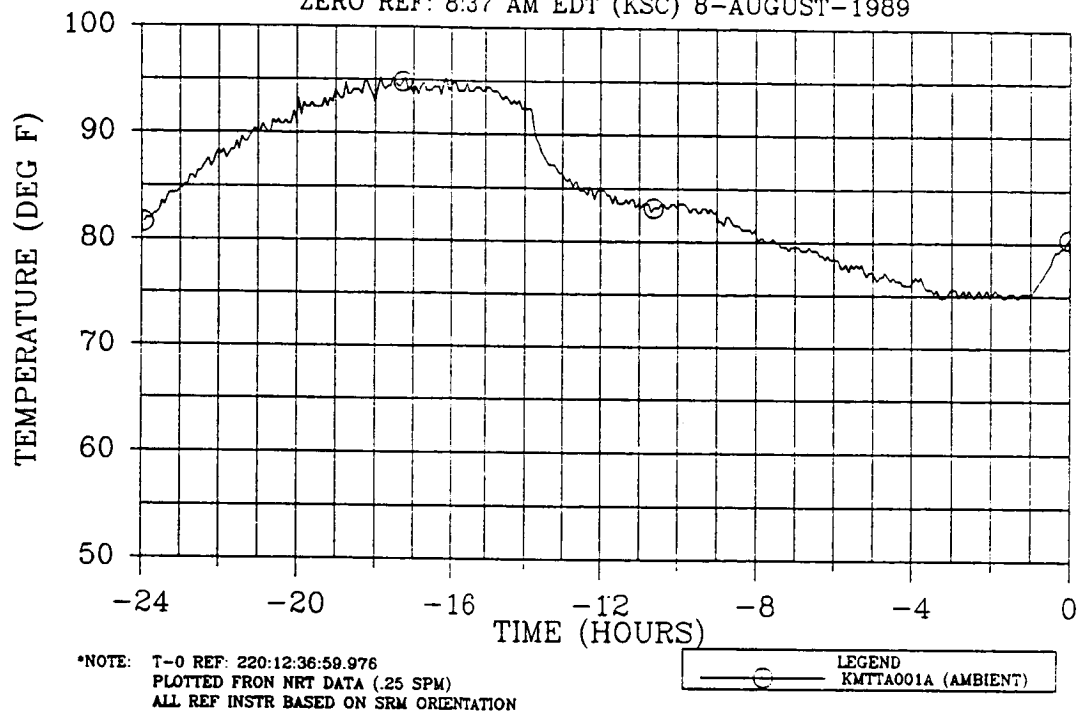


Figure 4.8-1. 360H005 (STS-28) Launch—24-hr Ambient Temperature at Camera Site No. 3

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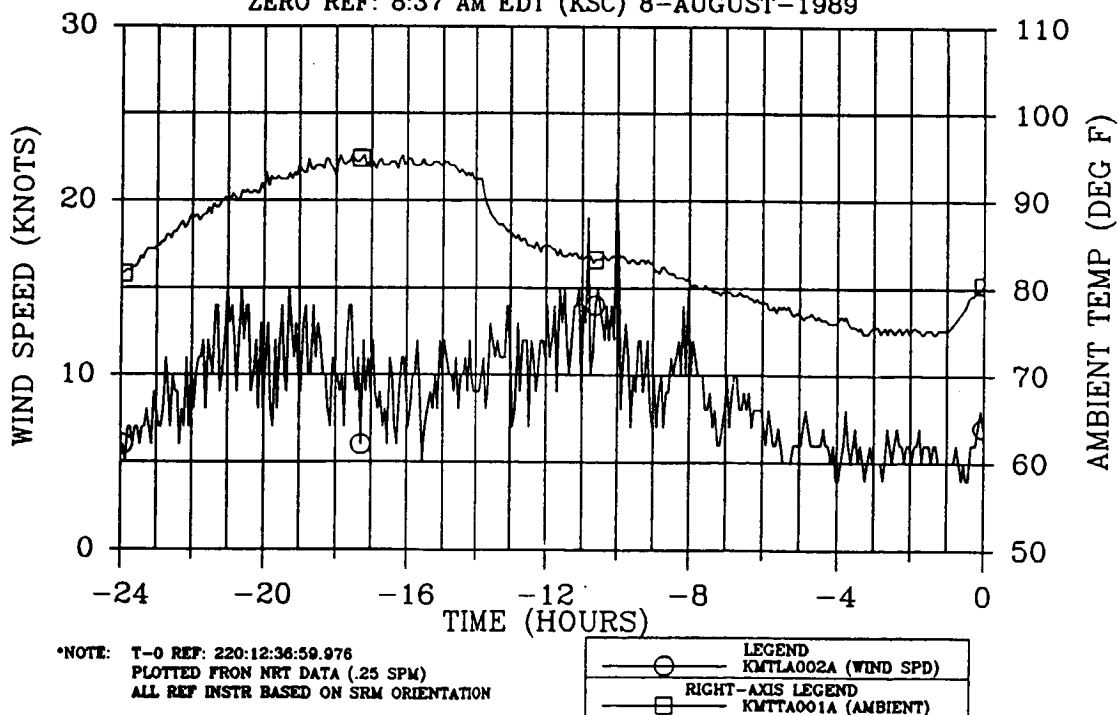


Figure 4.8-2. 360H005 (STS-28) Launch—24-hr Wind Speed at Camera Site No. 3 Overlaid With Ambient

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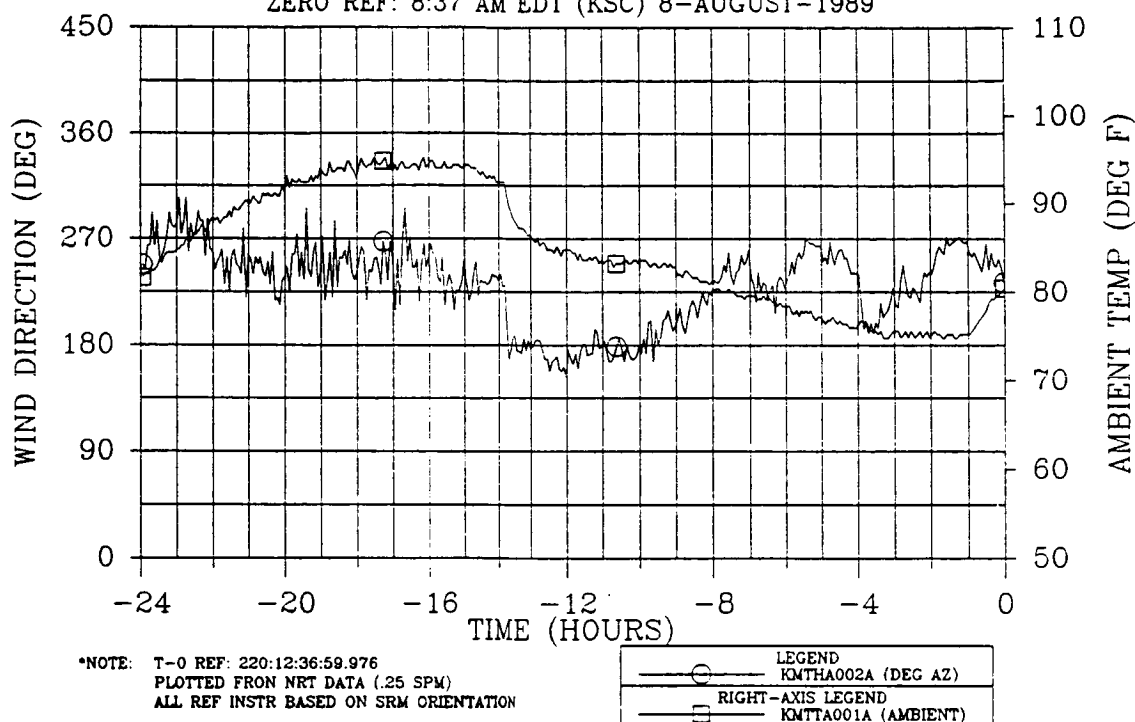


Figure 4.8-3. 360H005 (STS-28) Launch—24-hr Wind Direction at Camera Site No. 3 Overlaid With Ambient

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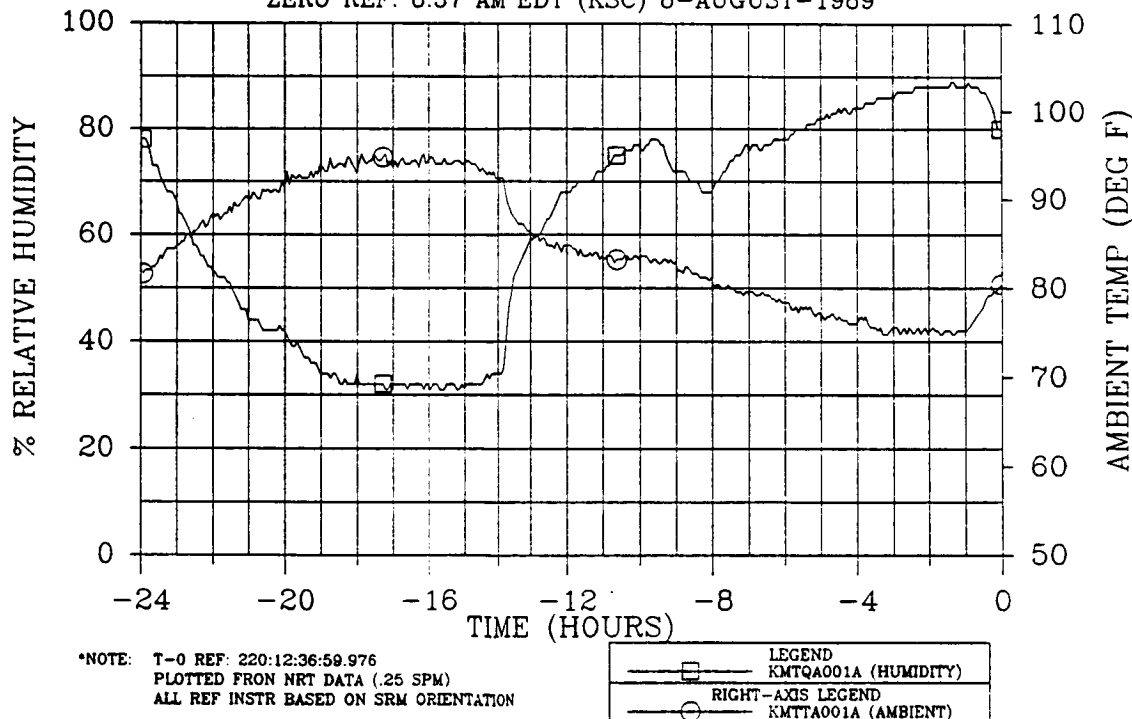


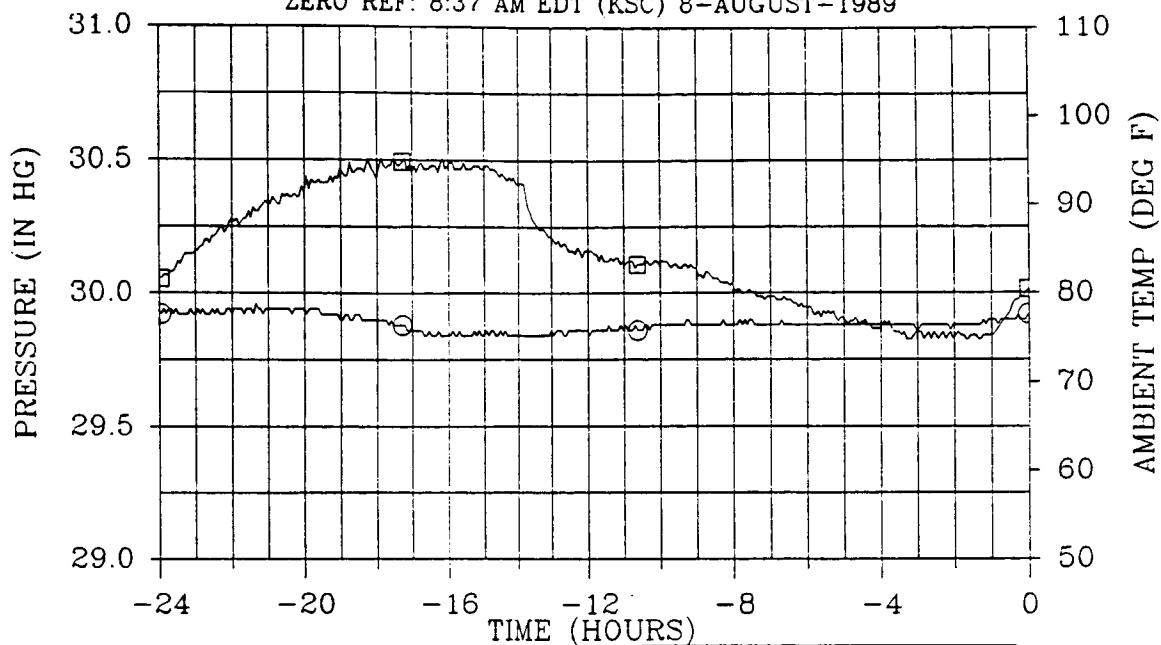
Figure 4.8-4. 360H005 (STS-28) Launch—24-hr Humidity at Camera Site No. 3 Overlaid With Ambient

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*NOTE: T-0 REF: 220:12:36:59.976
PLOTTED FROM NRT DATA (.25 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

LEGEND	
—○—	KMTPA001A
RIGHT-AXIS LEGEND	
—□—	KMTTA001A (AMBIENT)

Figure 4.8-5. 360H005 (STS-28) Launch—24-hr Barometric Pressure at Camera Site No. 3 Overlaid With Ambient

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Table 4.8-4. STS-28R August Historical On-Pad Temperature Predictions
Versus Actual GEI Countdown Data (*F) (LCC timeframe
temperatures are included)

Component	Daily Cycling		T-6 Hr to T-5 Min		LCC
	August Historical	Actual GEI	August Historical	Actual GEI	
Igniter Joint					
RH	81-91	79-85	85-100	83-100	71-123*
LH	81-91	80-86	85-100	83-100	71-123
Field Joint					
RH Forward	73-94	80-95	97-107	95-101	85-122**
LH Forward	73-93	79-90	98-103	93-99	85-122
RH Center	73-94	89-94	98-107	94-102	85-122
LH Center	74-92	80-92	97-103	92-99	85-122
RH Aft	73-93	80-95	98-107	94-102	85-122
LH Aft	74-92	80-91	97-102	94-103	85-122
Case-to-Nozzle Joint					
RH	76-87	81-83	83-87	82-85	75-115
LH	76-87	8-82	83-87	82-83	75-115
Flex Bearing					
Aft End Ring					
RH	76-87	80-82	83-87	82-83	NA-115
LH	76-87	82-85	83-87	82-85	NA-115
Case Acreage (deg)					
RH 45	73-90	77-97	74-87	77-88	--
135	74-94	80-95	75-87	75-85	--
215	75-91	75-91	75-83	75-83	--
270	76-90	74-90	74-83	74-83	35-NA
325	75-91	75-93	75-83	75-83	--
LH 45	65-93	77-90	75-83	77-83	--
135	74-90	77-91	77-83	77-83	--
215	75-90	77-91	77-83	77-82	--
270	75-92	77-90	75-83	77-83	35-NA
325	76-93	75-90	75-83	75-83	--
Local Environment					
Temperature	74-86	75-94	74-80	75-83	38-99
Windspeed (kt)	9	4-20	9	4-14	24
Wind Direction	SE	S to W	SE	S to W	SW to SE
Cloud Cover		Clear		Clear	

*Lower LCC redline value for igniter sensor raised from 66° to 71°F
for STS-28R

**Lower LCC redline field value for field joint sensor would drop from
85° to 68°F in case of complete heater failure

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4.8.3.5 Launch Commit Criteria. No LCC thermal violations were noted. Measured GEI and heater sensor data for the end of the LCC timeframe (T-5 min) are presented in Table 4.8-5 and are compared there to the LCC requirements.

The igniter heaters were activated for approximately 20 hr and performed as expected. Cooldown, after heater shutoff, occurred over an approximate 8-hr period and resulted in T-5 min igniter sensor temperatures of 83°F. These 83°F temperatures were only 1°F higher than the preactivation temperatures. A review of previous countdowns shows that the igniter heaters have a greater effectivity during colder conditions. That is to say, the amount of heat soak is somewhat proportional to overall heater activation time which, in turn, is greater when the temperature is colder.

The six field joint heaters performed adequately and as expected with an 11°F sensor temperature range from 92° to 103°F during the LCC timeframe. The secondary LH forward field joint heater failed the DWV test prior to SIT, but did function properly during the SIT. This heater was not powered up during the actual countdown. One minor electrical issue was worked during the countdown. A voltage spike was seen in the LH forward field joint heater circuitry at the time of heater activation and again during normal heater operation. Both voltage spikes resulted in immediate heater shutdown by the heater controller. Since there was no accompanying current spike with either voltage spike, the determination was made that the voltage spikes were due to faulty instrumentation readings and, therefore, the heater was reactivated.

All 24 field joint sensors recorded temperatures in the expected range. Two and a half weeks prior to launch the minimum field joint LCC redline value was reduced from 85° to 68°F. This modification was a change unique to STS-28R and was a precaution taken in the event of a primary heater failure on the LH forward field joint. (The redundant LH forward field joint heater failed the DWV test).

The SRB aft skirt purge was temporarily activated, for checkout purposes, approximately 16 hr before launch. Because of the warm ambient and component temperatures the purge operation was not permanently activated until T-15 min. This was done in accordance with the OMI which instructs the

Table 4.8-5. STS-28R LCC Timeframe End (T-5 min) On-Pad Temperature Predictions Versus August Historical and Actual GEI Data

<u>Component</u>	<u>L-12 hr Predictions*</u>	<u>August Historical</u>	<u>Actual GEI</u>	<u>LCC</u>
Igniter Joint				
RH	88-92	86-88	83-83	71-123**
LH	88-92	86-88	83-83	71-123
Field Joint				
RH Forward	96-108	97-107	98-101	85-122***
LH Forward	96-102	98-103	95-99	85-122
RH Center	96-108	98-107	97-101	85-122
LH Center	96-102	97-103	96-98	85-122
RH Aft	96-108	98-107	98-102	85-122
LH Aft	96-102	97-102	96-100	85-122
Case-to-Nozzle Joint				
RH	82-88	85-87	82-83	75-115
LH	82-88	85-87	82-82	75-115
Flex Bearing				
Aft End Ring				
RH	82-88	85-87	82-83	NA/115
LH	82-88	85-87	82-85	NA/115
Case Acreage (deg)				
RH 45	--	86-87	82-88	--
135	--	87-88	80-83	--
215	--	82-83	77-78	--
270	78-84	82-83	74-78	35-NA
325	--	82-83	77-80	--
LH 45	--	82-83	77-78	--
135	--	82-83	77-78	--
215	--	82-83	77-77	--
270	78-84	82-83	77-82	35-NA
325	--	82-83	77-78	--
Local Environment				
Temperature	80	80	80	38-99
Windspeed (kt)	--	9	6-8	24
Wind Direction	--	SE	SW	SW to SE
Cloud Cover			Clear	

*Predictions for anticipated launch window at T-5 min

**Lower LCC limit for igniter sensor raised from 66° to 71°F for STS-28R

***Lower limit for field joint sensor would drop from 85° to 68°F in case of complete heater failure

operator to control the "SRB Flow Rate Purge" as required to maintain the following limits: 1) flex bearing at 60° to 115°F and 2) case-to-nozzle joint at 75° to 115°F.

4.8.3.6 Prelaunch Thermal Data Evaluation. Figures 4.8-6 through 4.8-10 show locations of the GEI and joint heater sensors for the igniter adapter, field joint, case acreage, nozzle region, and aft exit cone, respectively. Figures 4.8-11 through 4.8-40 present August historical predictions. These predictions are based on event sequencing, as specified in Table 4.8-6. Figures 4.8-41 through 4.8-97 show actual STS-28R countdown data.

Actual GEI and joint heater sensor data were in agreement, for the most part, with August historical on-pad predictions. The predicted igniter sensor, case-to-nozzle joint, and flex bearing aft end ring temperatures varied more during a daily cycle than the actual GEI temperatures. The actual high temperature the day before launch was 8°F warmer than the normal August high temperature. The LCC time period (T-6 hr to T-5 min) predictions were in good agreement with the actual data given the fact that the aft skirt purge system did not operate (see Table 4.8-4). The T-5 min historical versus the L-12 hr predictions of launch time conditions, which incorporate an environmental update for the last 24 hr prior to launch, were in good agreement with most of the GEI. The predicted igniter sensor temperatures after cooldown were higher than the actual measured temperatures (see Table 4.8-5).

Postflight reconstructed predictions of GEI and igniter/field joint heater response have been performed using the actual environmental data from the 24 hr prior to launch. Two different predicting methods (one using historical solar radiation and the other using measured solar radiation) were used to compare with actual measured data. As can be seen, a much better prediction is attained when using measured solar radiation instead of the historical solar radiation. A few examples of these predictions, compared with actual measured sensor data, are found in Figures 4.8-98 through 4.8-113. Reasonable agreement is apparent in all areas except the ET attach ring, LH SRB systems tunnel, and the case-to-nozzle joint regions. In the future, modeling improvements (environment and detail) need to be made in

these regions. IR temperature measurements taken by the IR gun during the T-3 hr ice/debris team pad inspection were found to be anomalous and therefore were not reported. The STI temperature measurements were used along with the GEI measurements to monitor SRM surface temperatures. Temperatures varied between about 76° and 80°F during the T-3 hr pad inspection for both STI and GEI temperatures.

Table 4.8-6. STS-28R Analytical Timeframes for Estimating Event Sequencing of August Historical Joint Heater and GEI Sensor Predictions

<u>Time (hr)</u>	<u>Countdown Events in Analysis</u>
0	Midnight KSC EST (6 Aug 1989)
34	Igniter heater operation begins on 7 Aug 1989 (L-24 hr)
42	Aft skirt conditioning operation begins on 7 Aug 1989 (T-12 hr plus 4 hr for holds)
46	Field joint heater operation begins on 7 Aug 1989 (T-8 hr plus 4 hr for holds)
48	Induced environments due to ET refrigeration effects begins early on 8 Aug 1989 (T-6 hr plus 4 hr for holds)
51	Igniter heater shutoff/start cooldown (T-4 hr plus 3 hr for holds)
58	Assumed time for launch (8 Aug 1989)

Note: Figure 4.8-11 through 4.8-40 consist of a 2-deg plus 13-hour scenario.

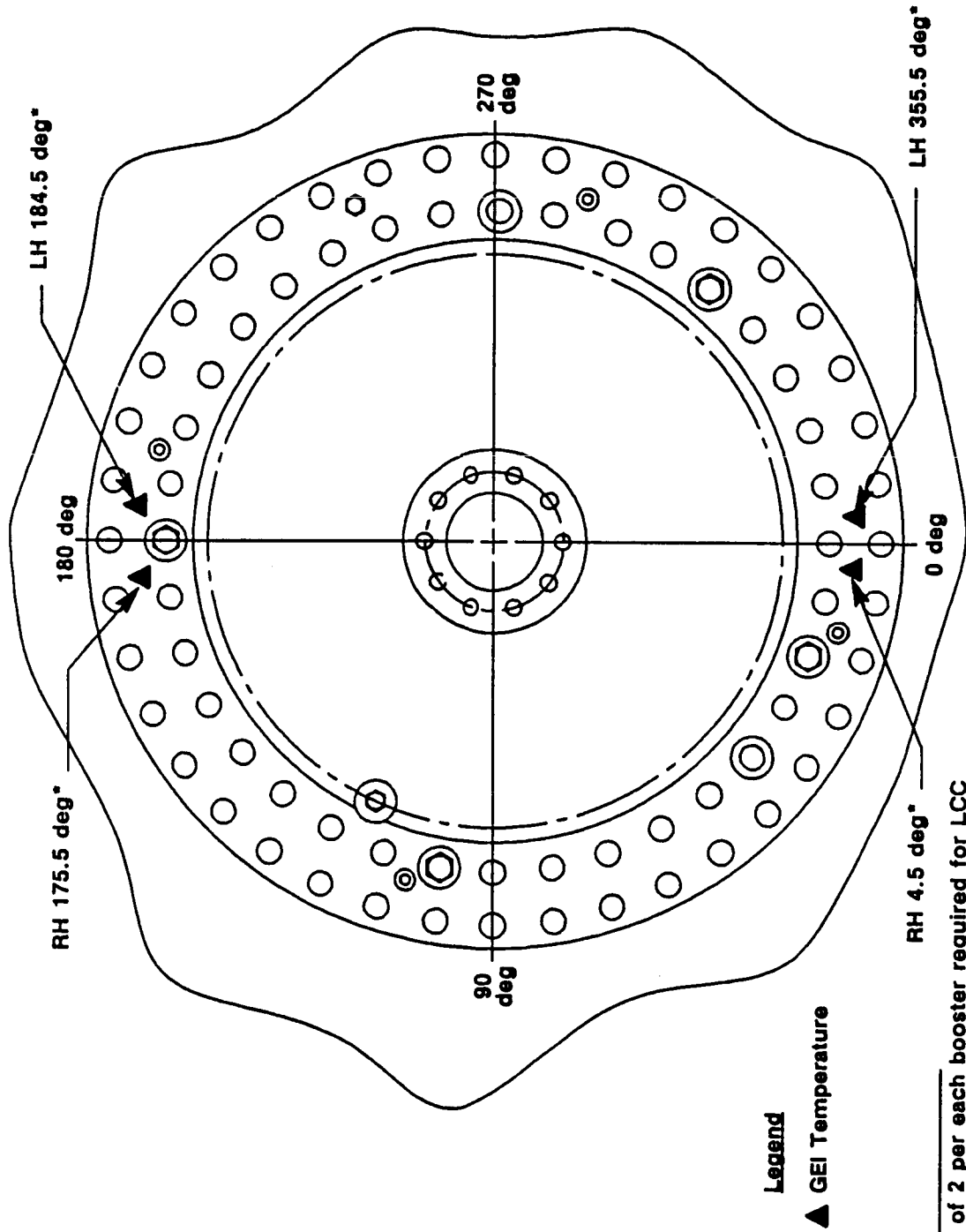
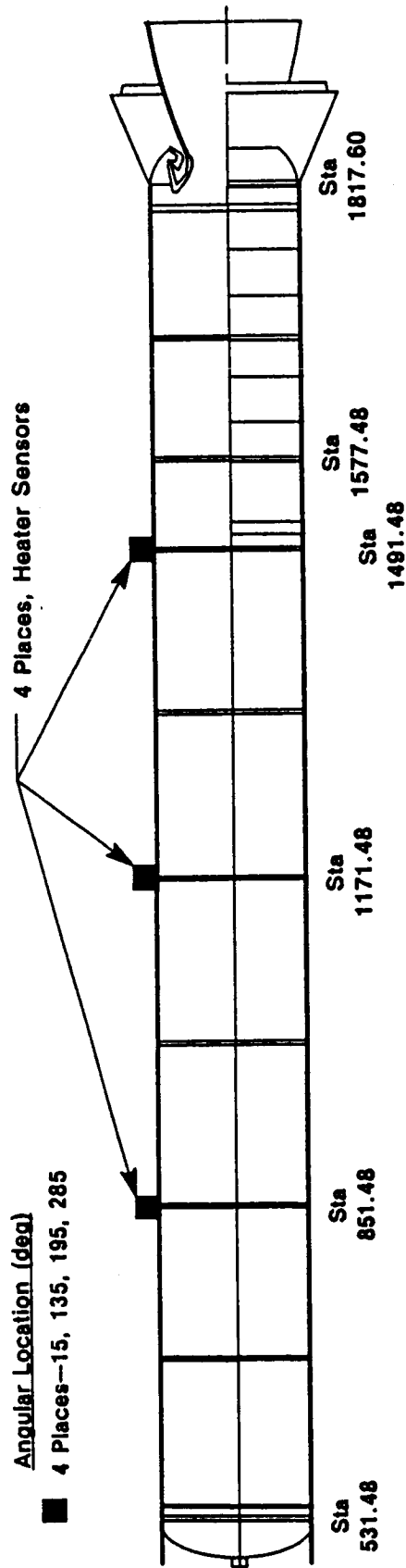


Figure 4.8-6. Forward Dome GEI



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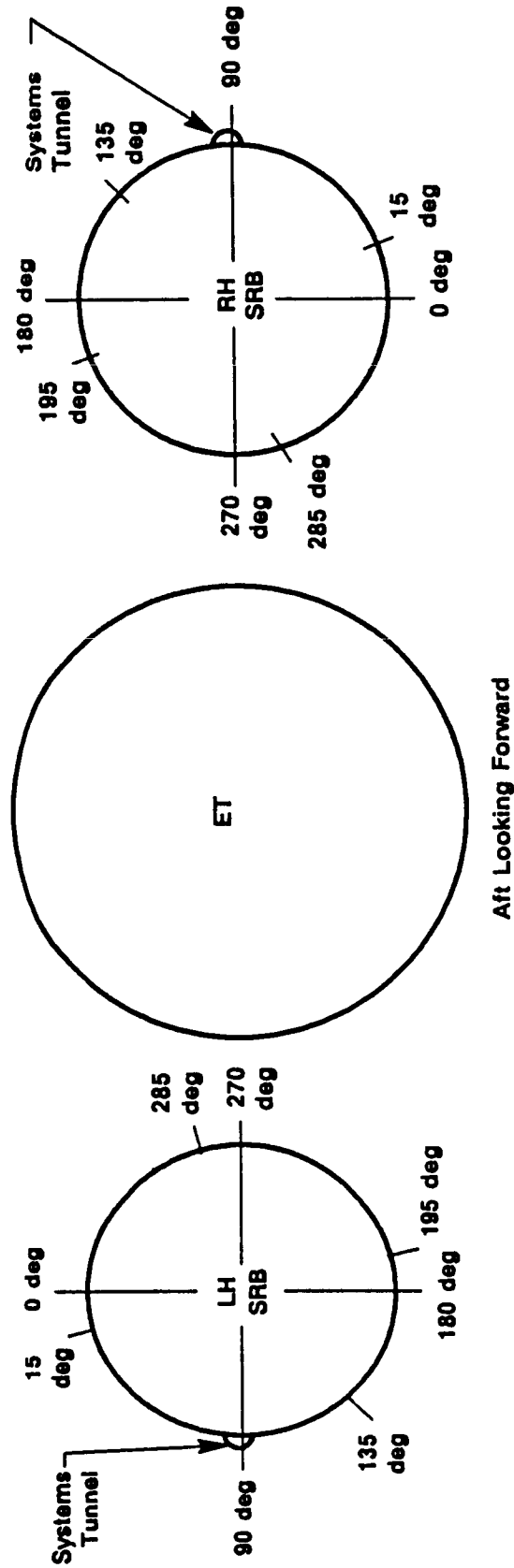


Figure 4.8-7. Field Joint Heater Temperature Sensors

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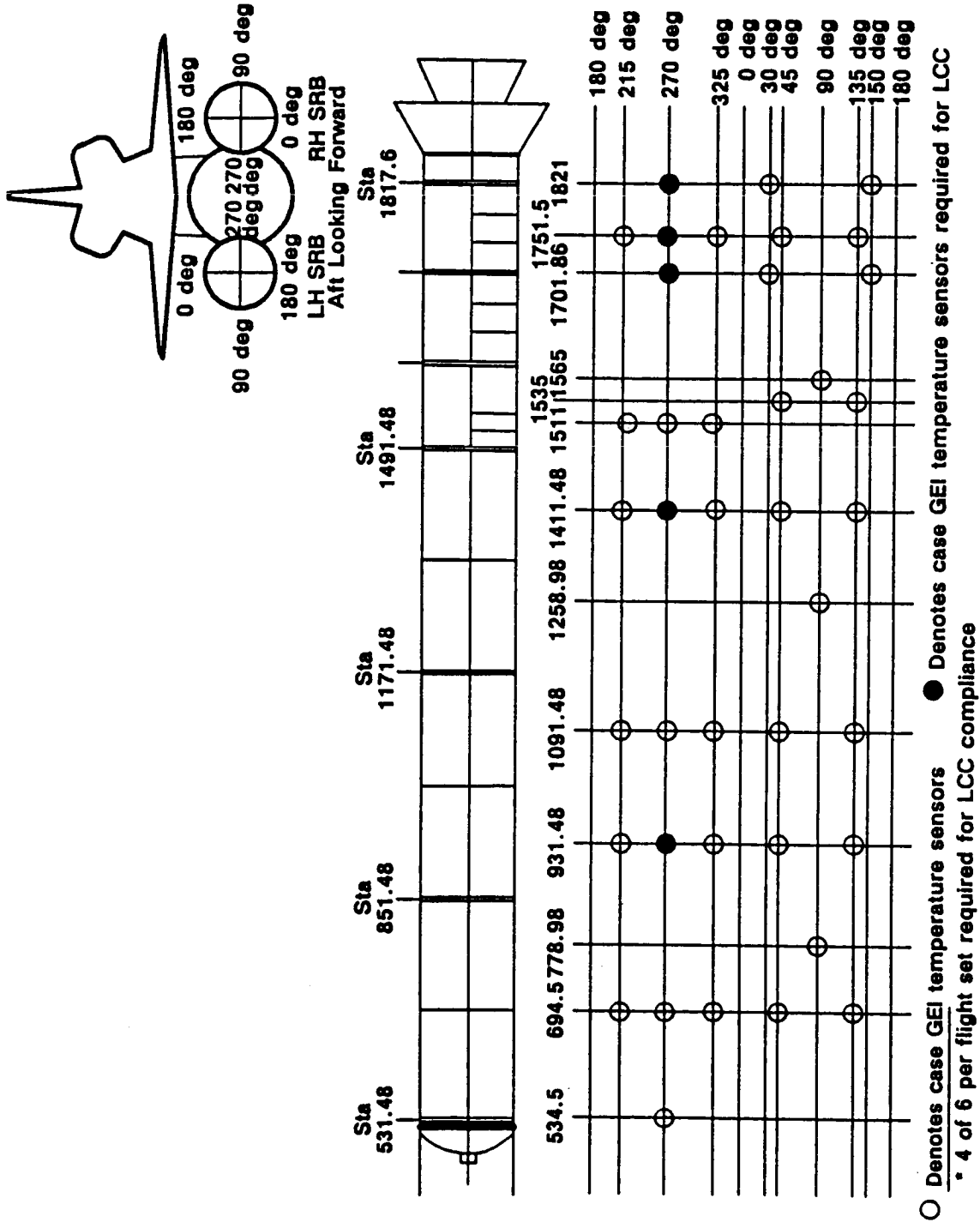


Figure 4.8-8. Case GEI

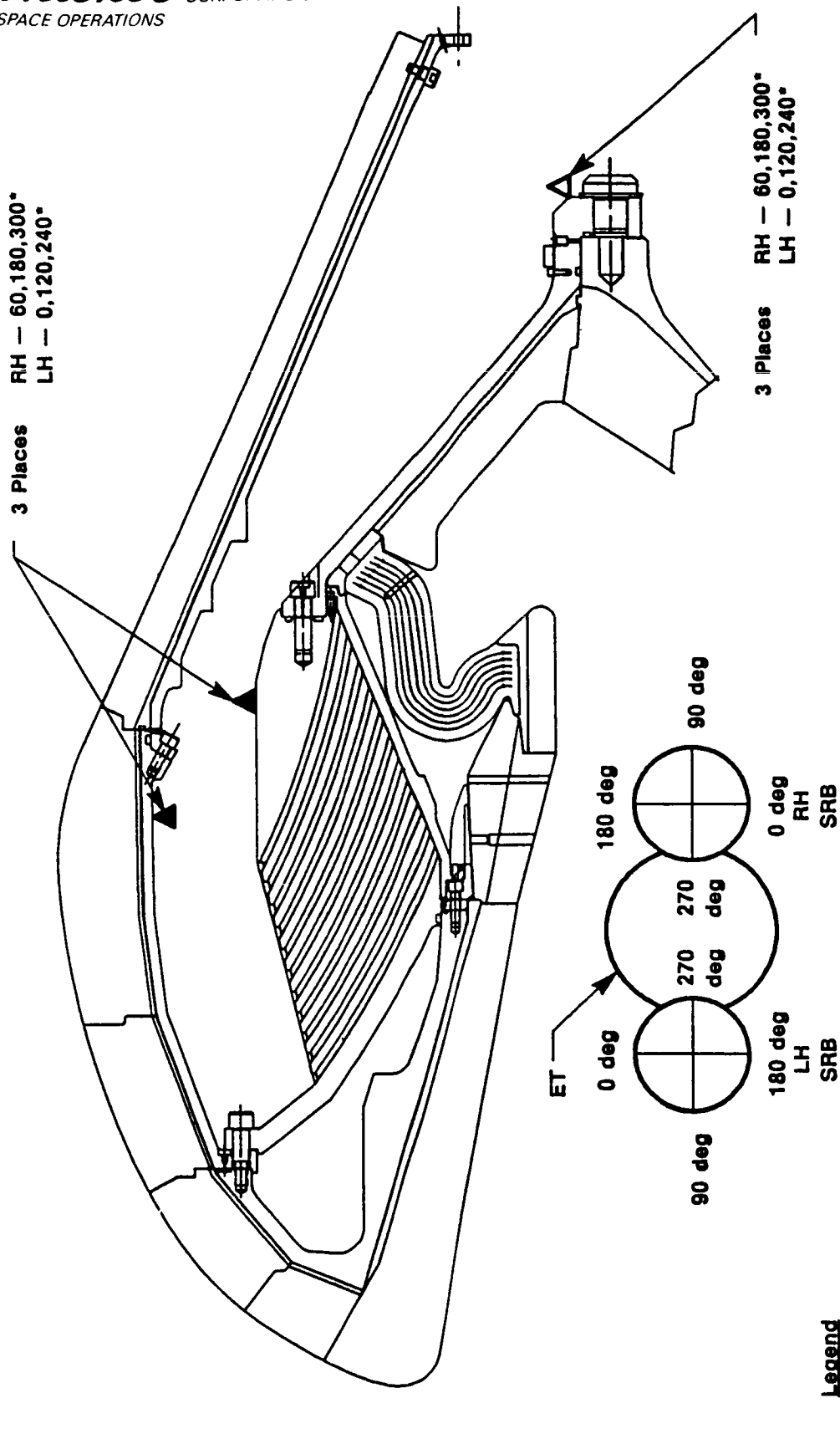
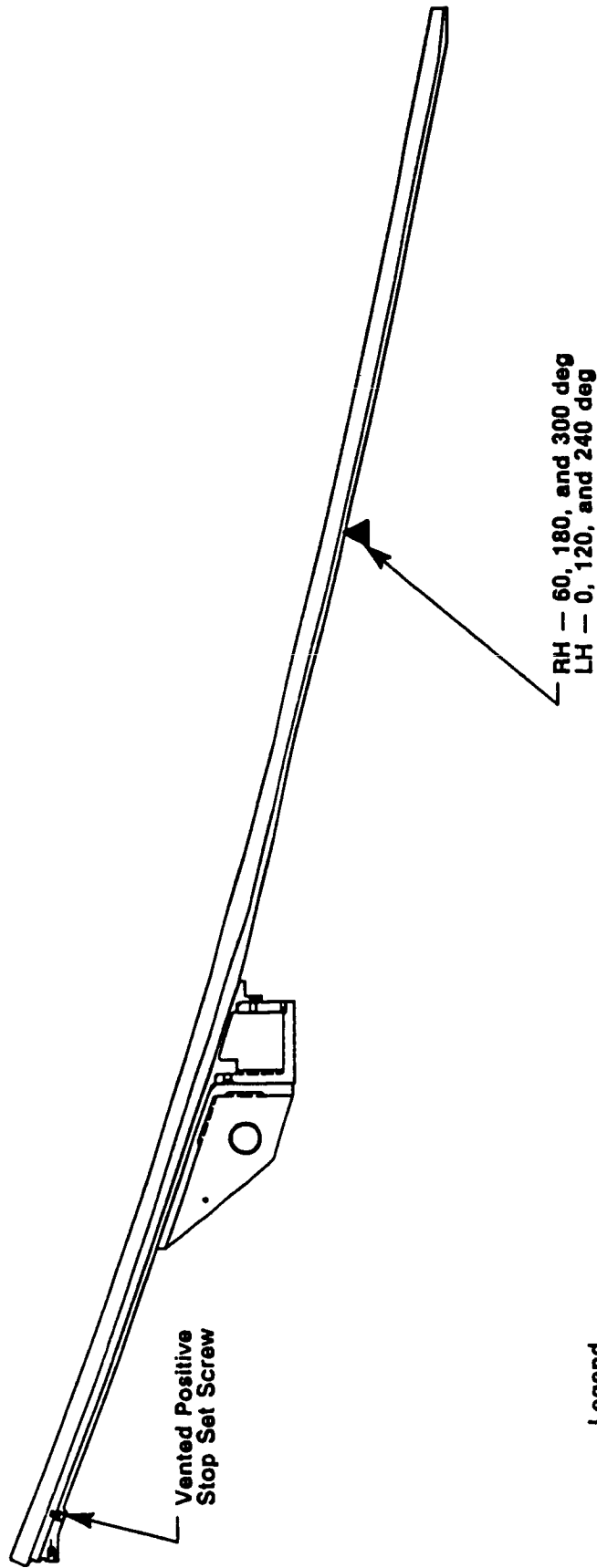


Figure 4.8-9. Nozzle GEI

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Legend
▲ GEI Temperature

Figure 4.8-10. Aft Exit Cone GEI

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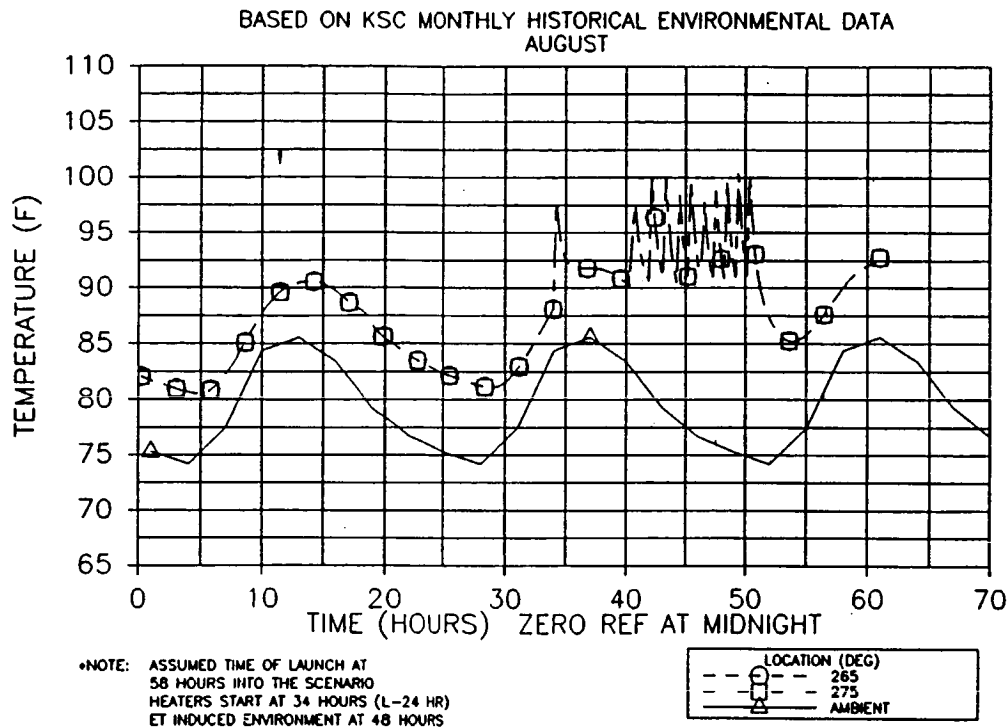


Figure 4.8-11. RH SRM Ignition System Region—Heater and GEI Temperature Prediction

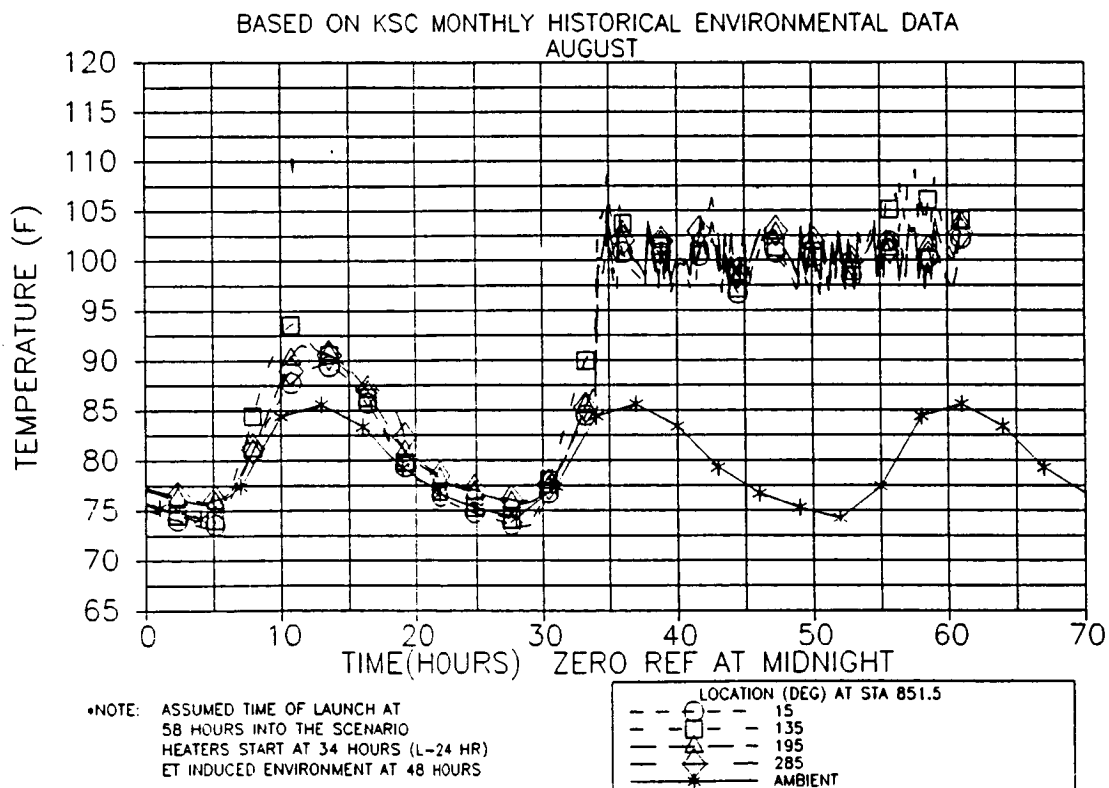


Figure 4.8-12. RH SRM Forward Field Joint—Heater Sensor Temperature Prediction

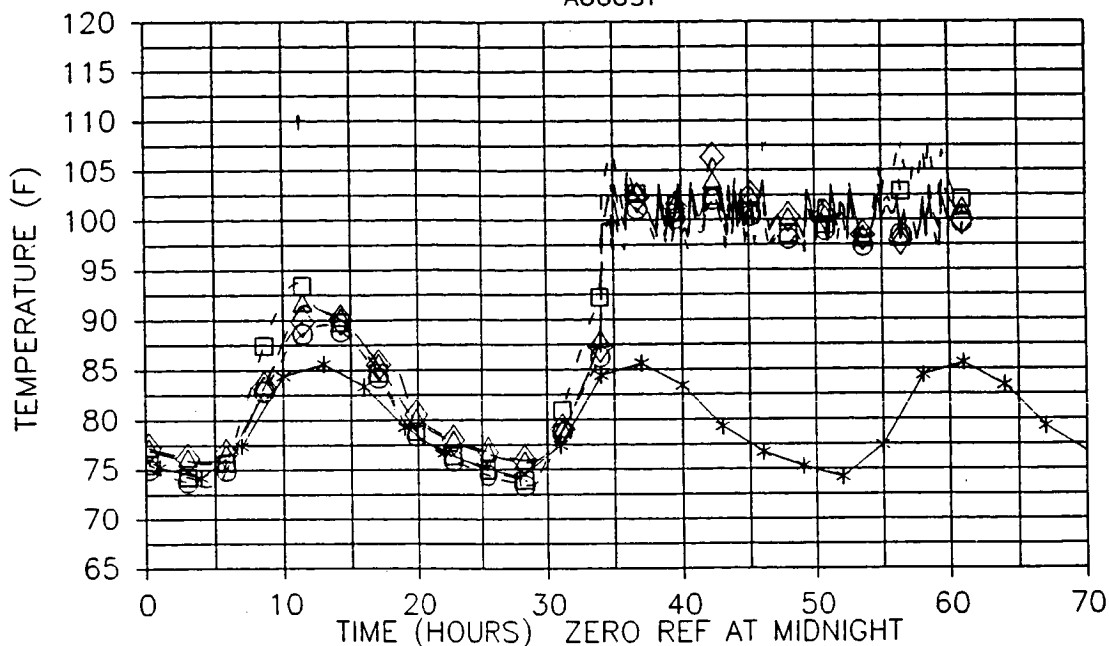


Figure 4.8-13. RH SRM Center Field Joint—Heater Sensor Temperature Prediction

BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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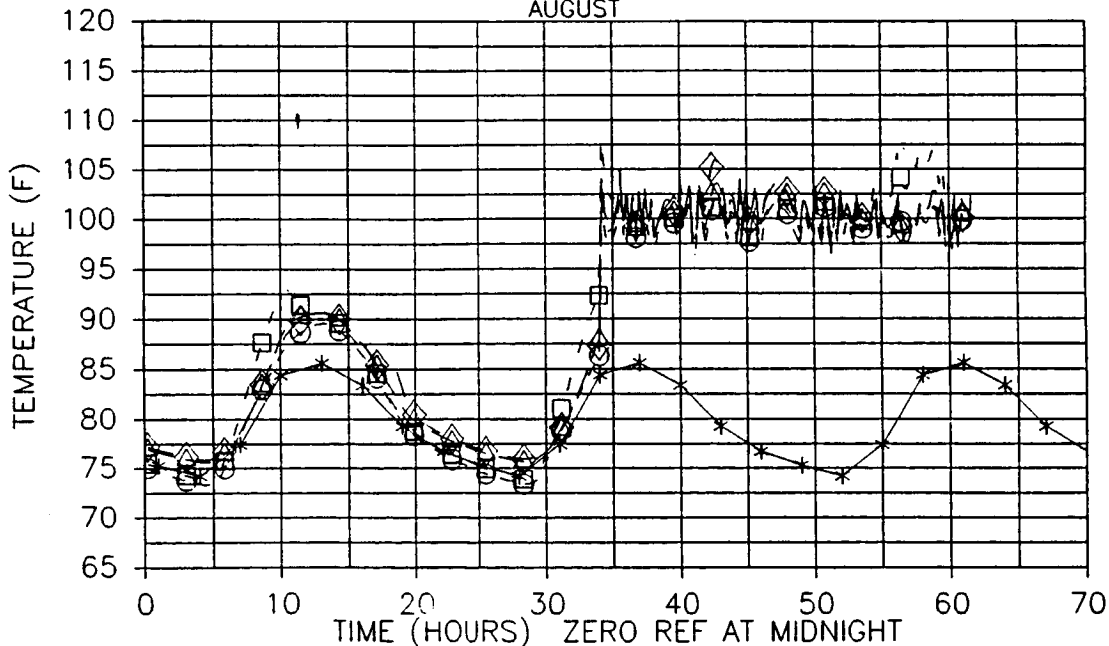


Figure 4.8-14. RH SRM Aft Field Joint—Heater Sensor Temperature Prediction

BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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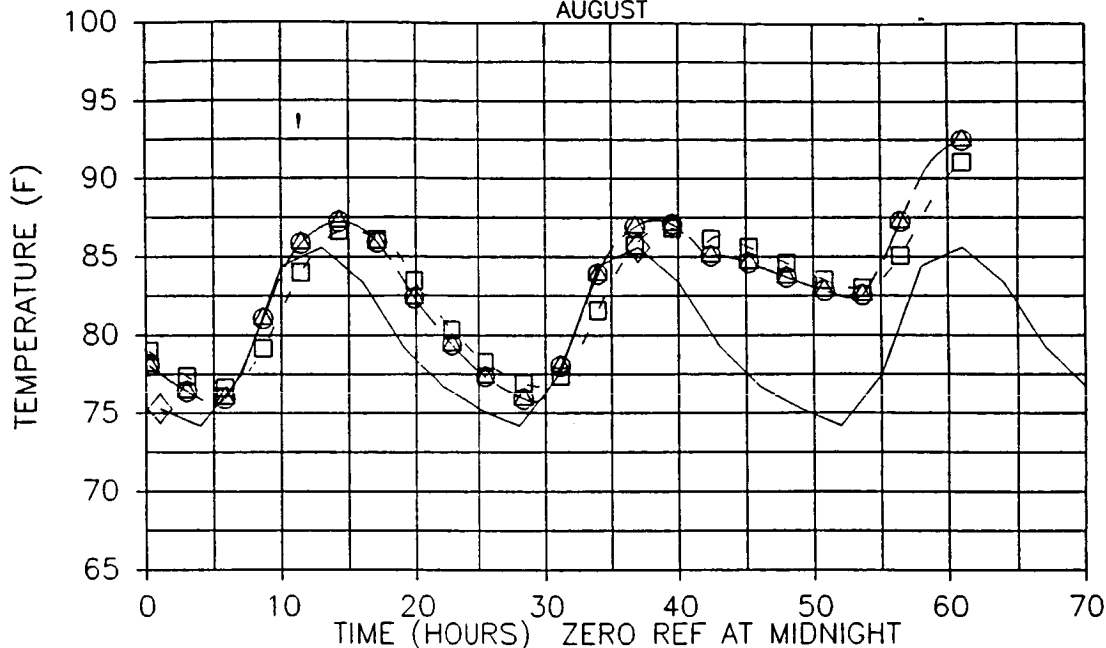


Figure 4.8-15. RH SRM Nozzle Region—GEI Sensor
Temperature Prediction

BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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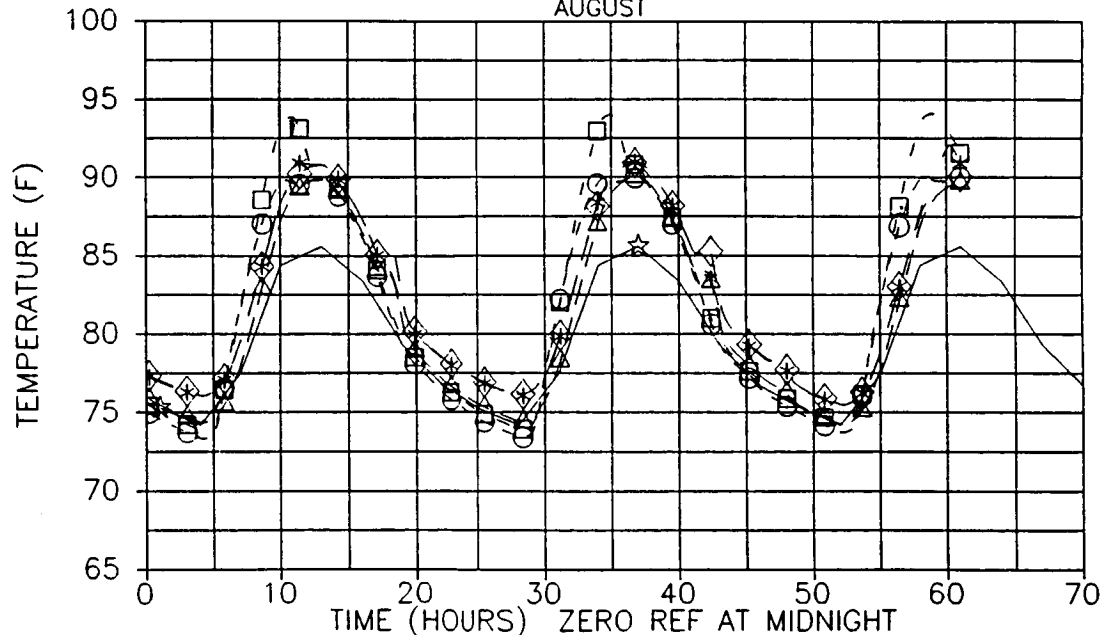


Figure 4.8-16. RH SRM Forward Case Acreage—GEI Sensor
Temperature Prediction

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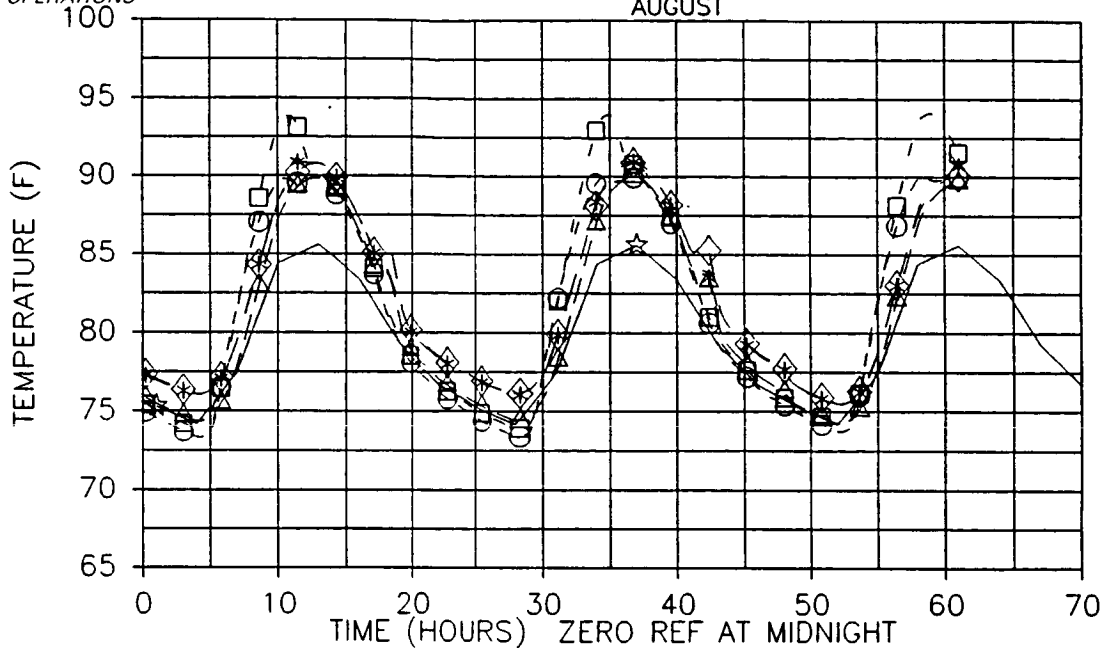


Figure 4.8-17. RH SRM Forward Center Case Acreage—GEI Sensor Temperature Prediction

BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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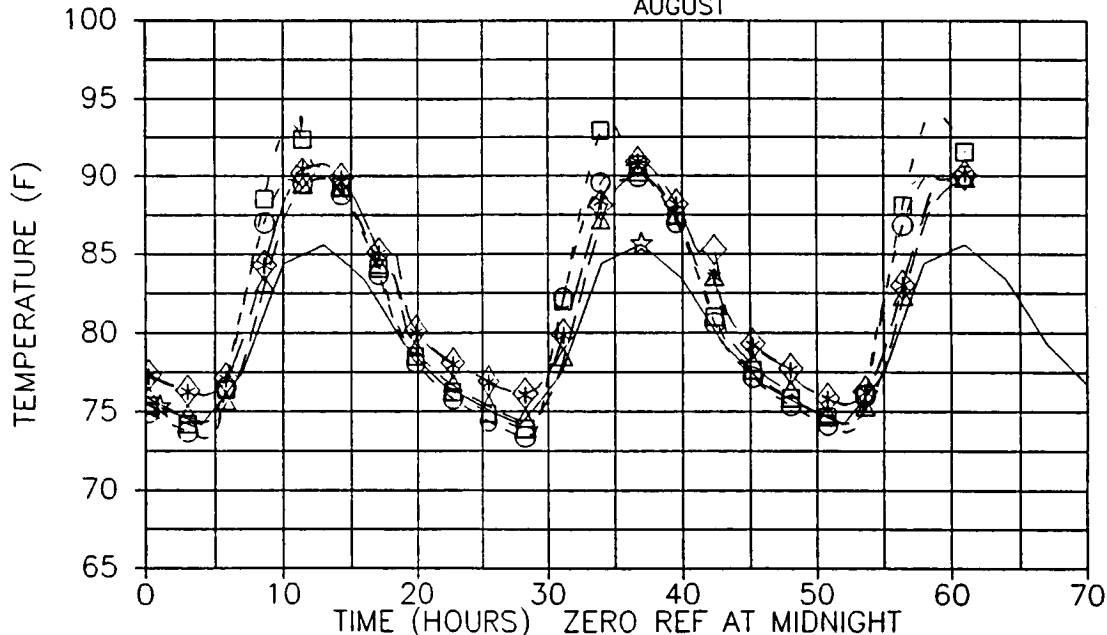


Figure 4.8-18. RH SRM Aft Center Case Acreage—GEI Sensor Temperature Prediction

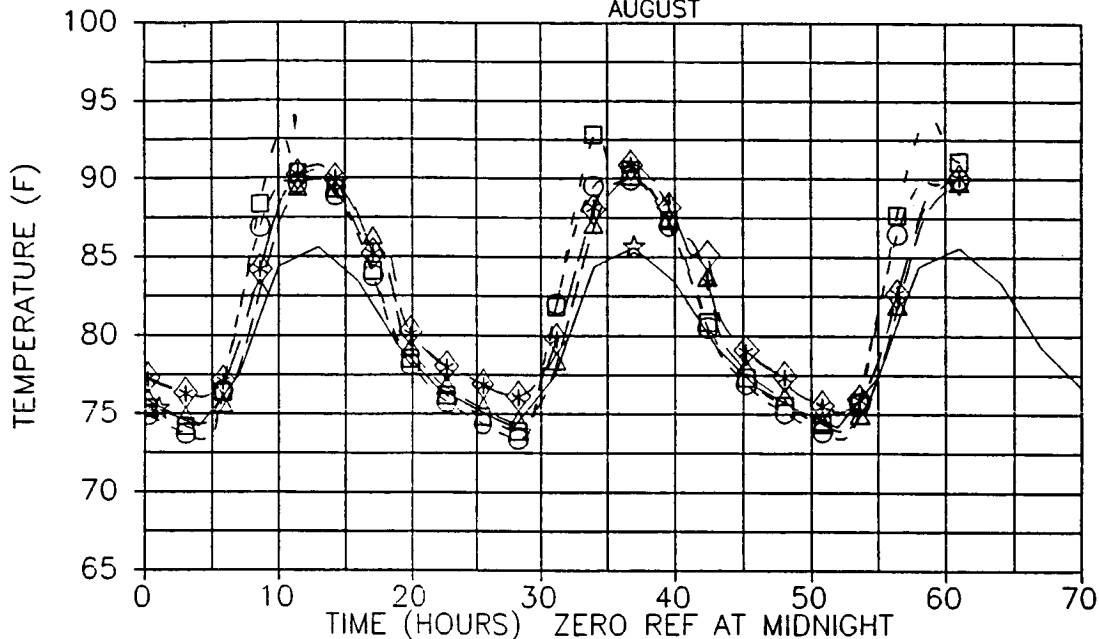


Figure 4.8-19. RH SRM Aft Case Acreage—GEI Sensor Temperature Prediction

BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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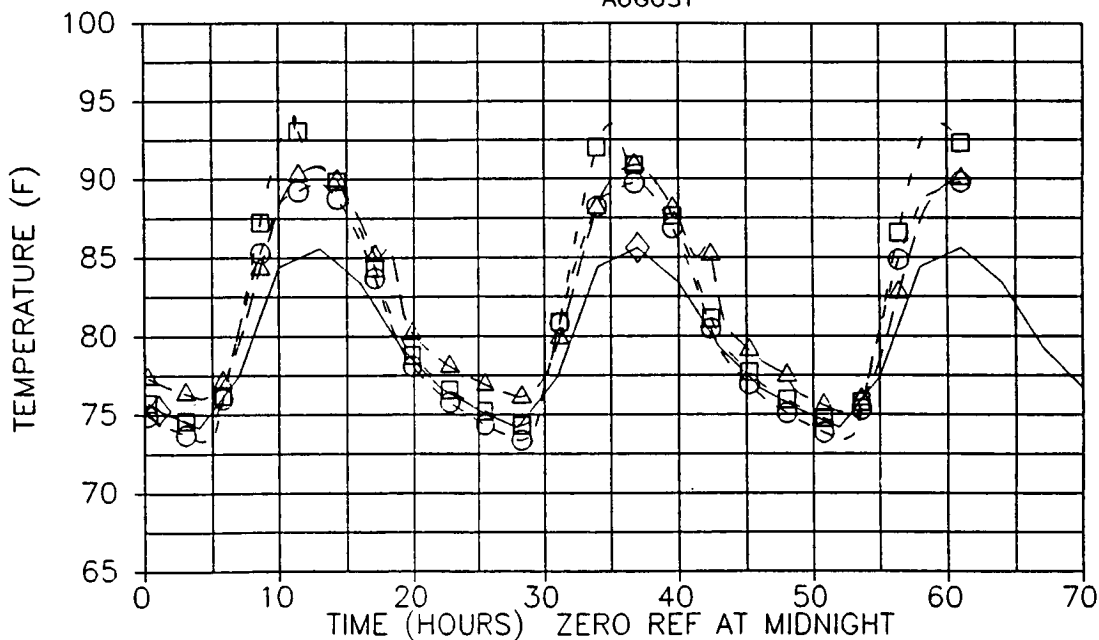


Figure 4.8-20. RH SRM Forward Dome Factory Joint—GEI Sensor Temperature Prediction

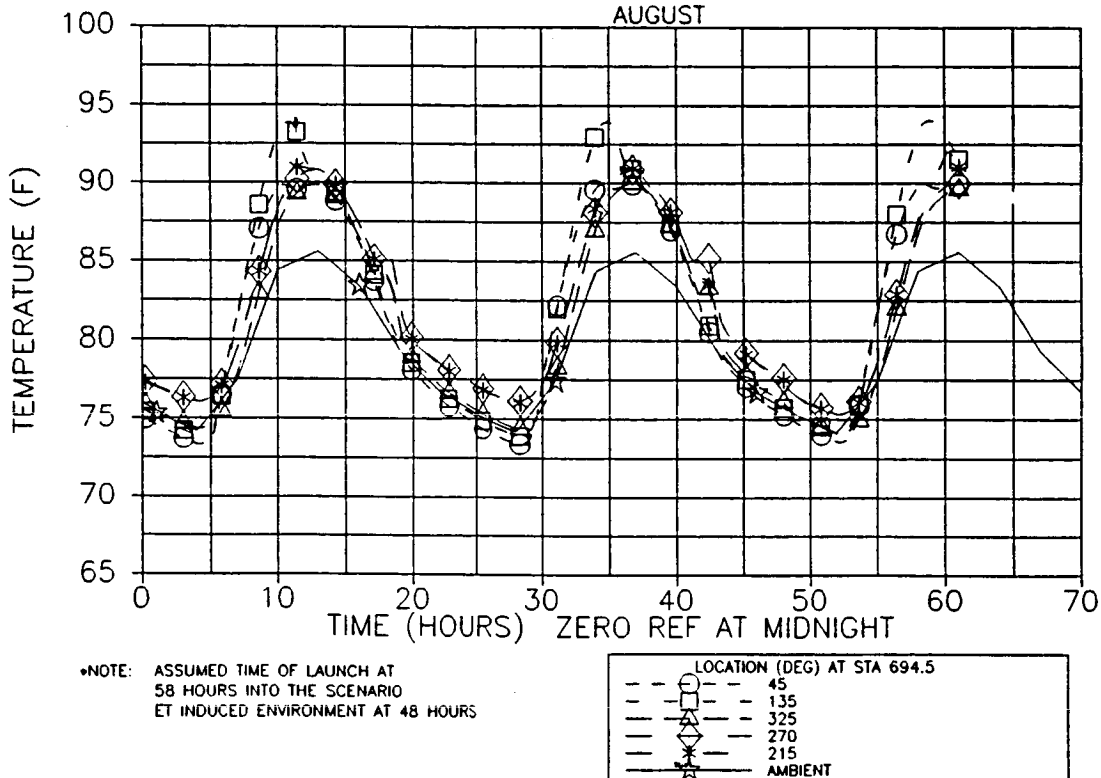


Figure 4.8-21. RH SRM Forward Factory Joint—GEI Sensor Temperature Prediction

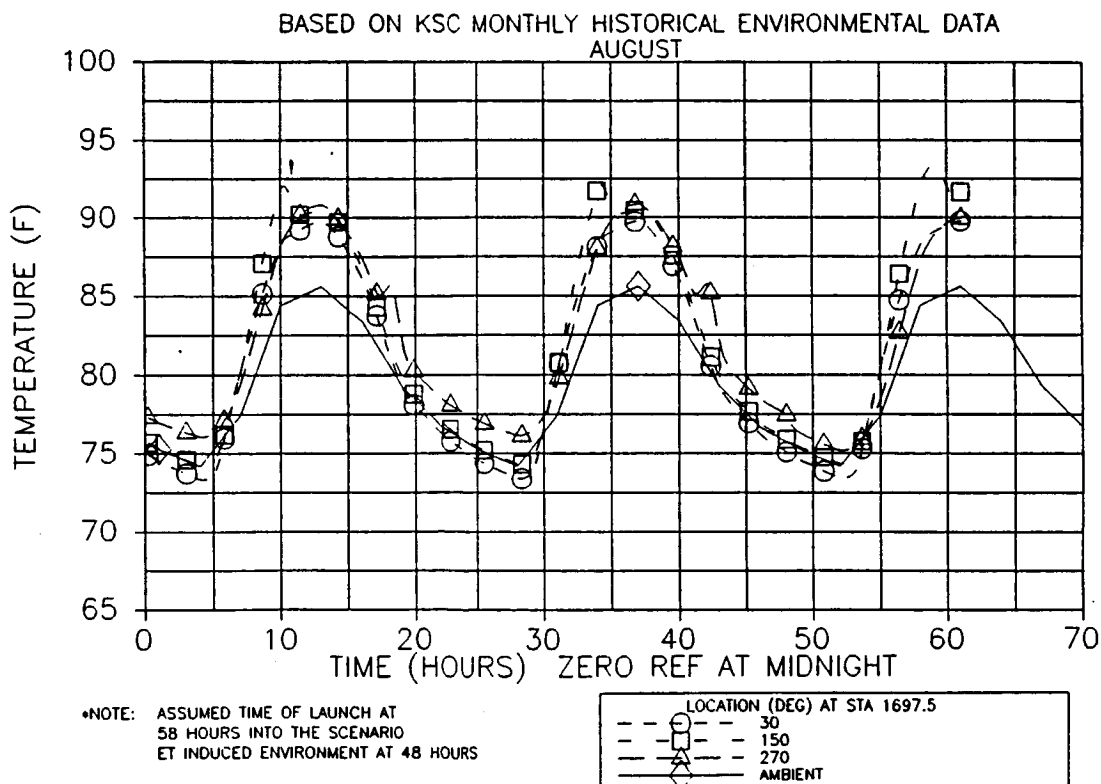


Figure 4.8-22. RH SRM Aft Factory Joint—GEI Sensor Temperature Prediction

BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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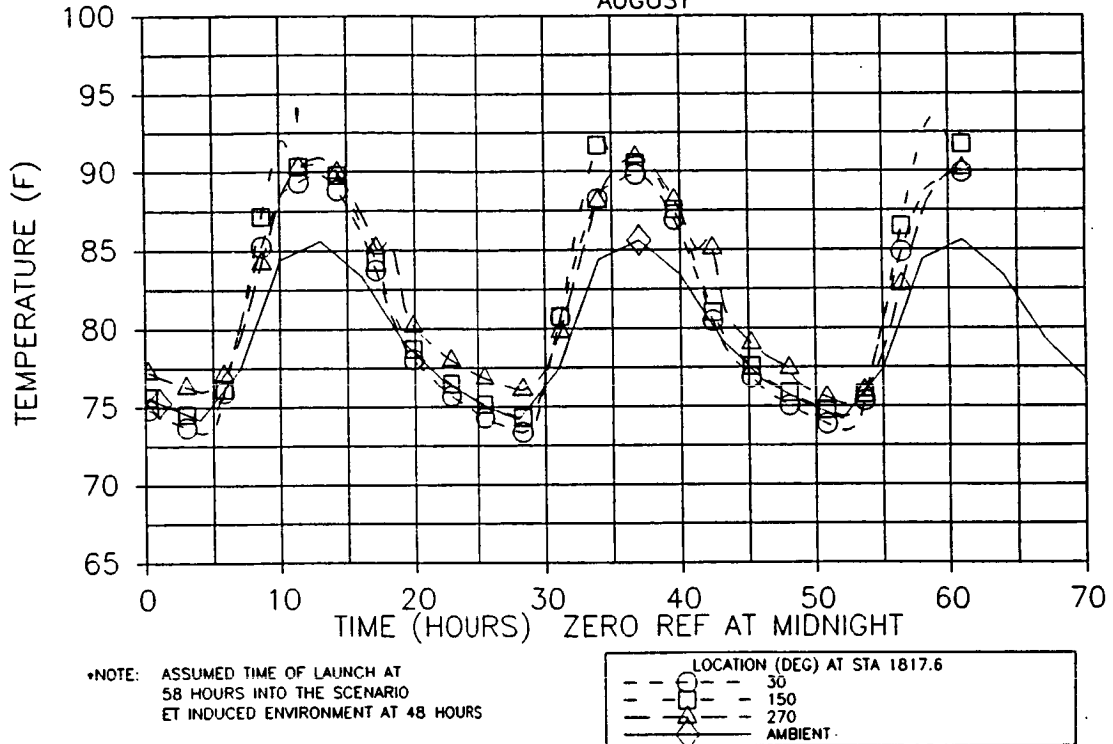


Figure 4.8-23. RH SRM Aft Dome Factory Joint—GEI Sensor Temperature Prediction

BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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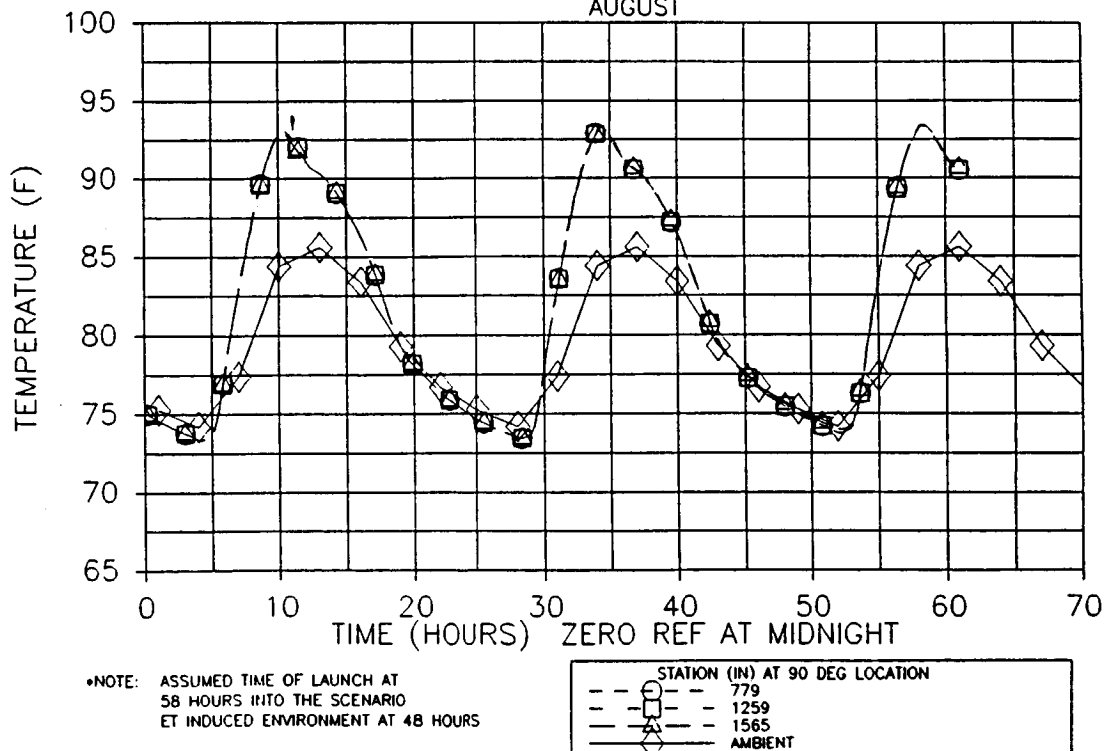


Figure 4.8-24. RH SRM Tunnel Bondline—GEI Sensor Temperature Prediction

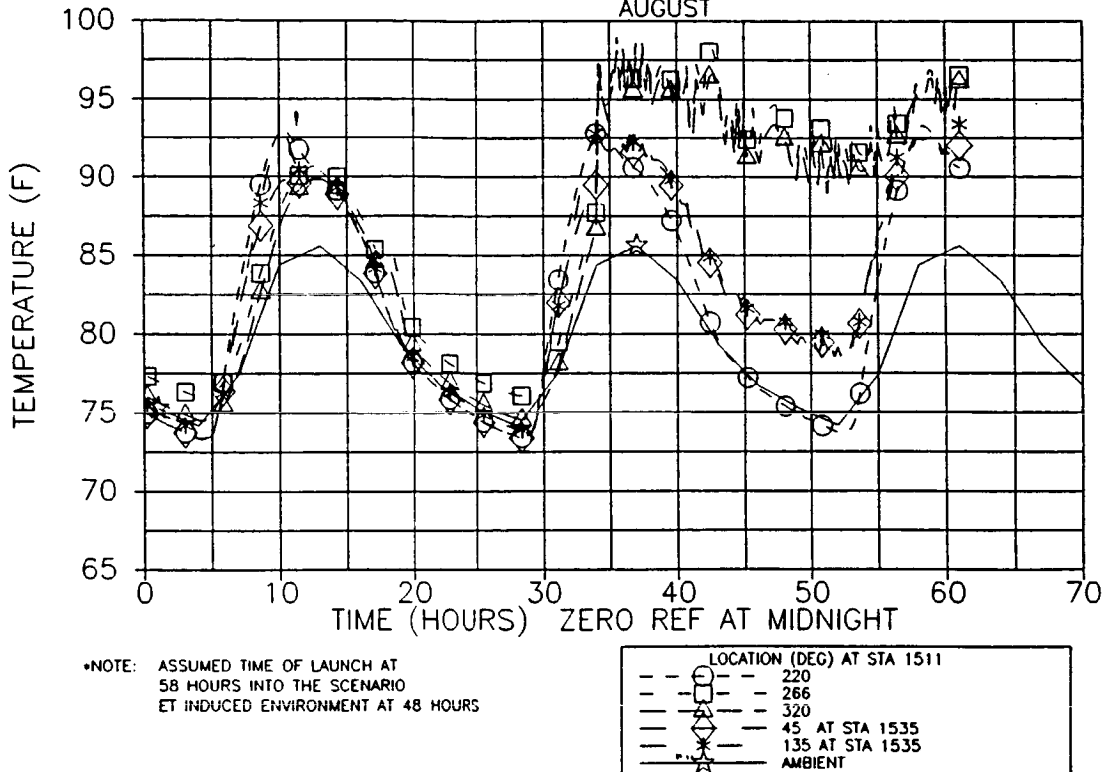


Figure 4.8-25. RH SRM ET Attach Region—GEI Sensor Temperature Prediction

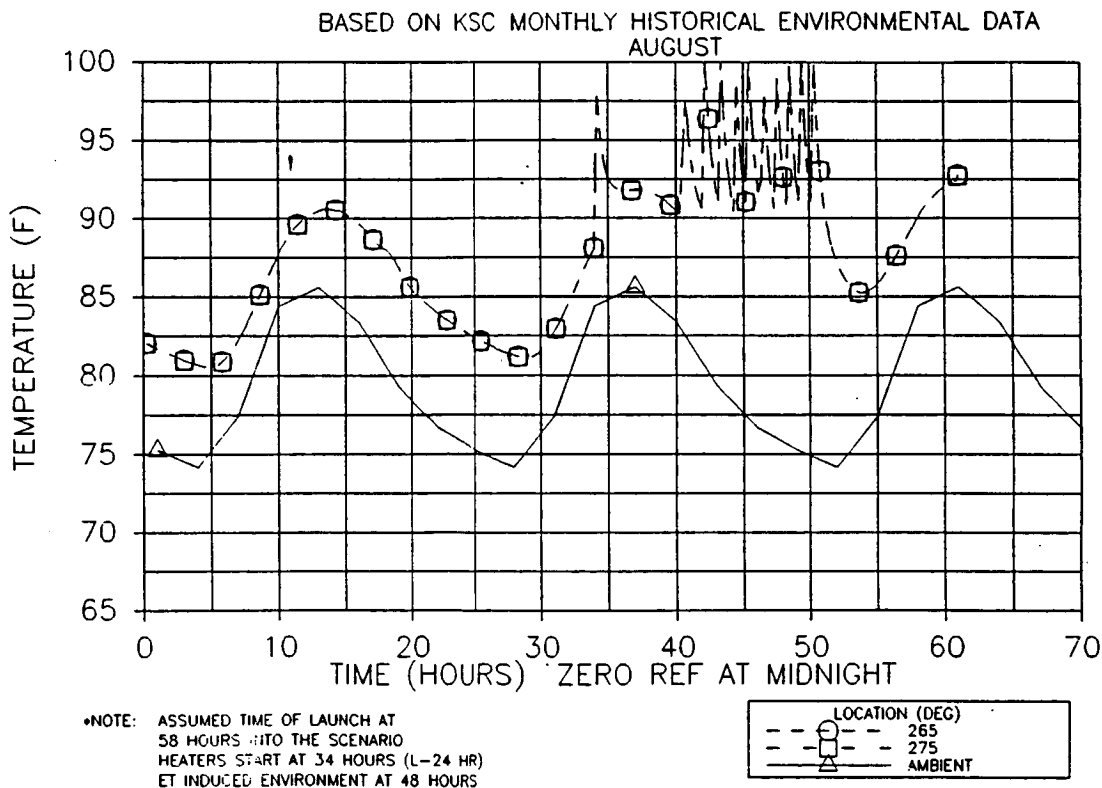


Figure 4.8-26. LH SRM Ignition System Region—Heater and GEI Sensor Temperature Prediction

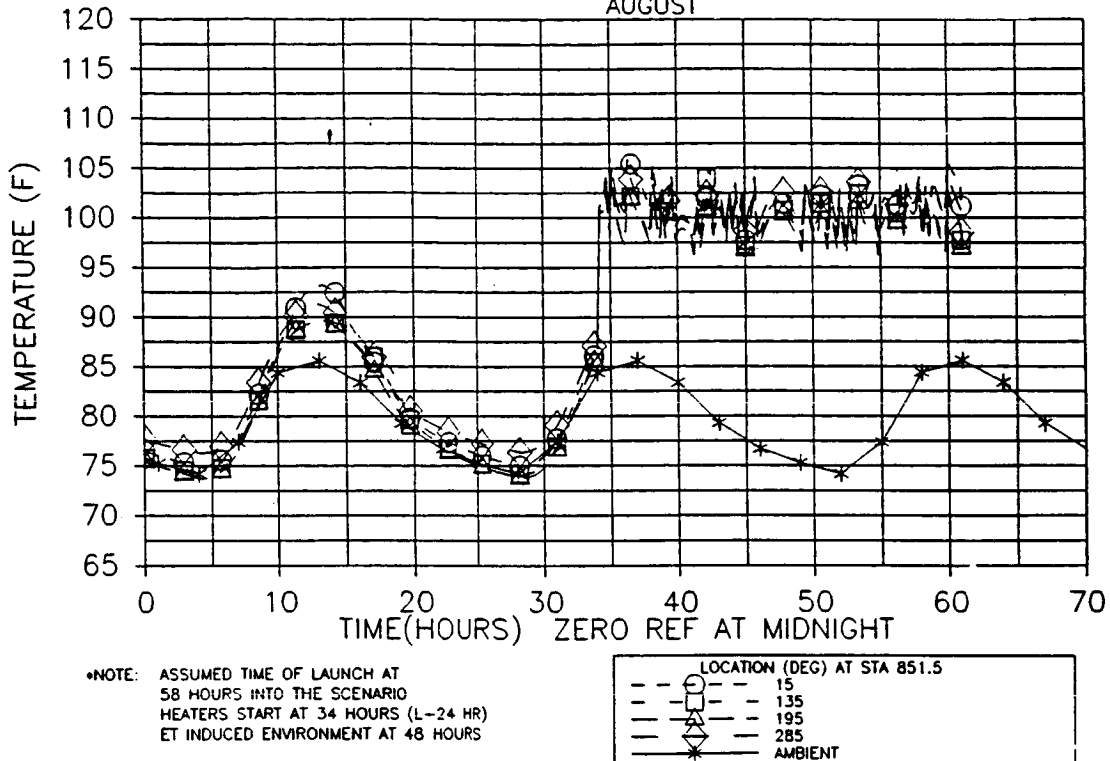


Figure 4.8-27. LH SRM Forward Field Joint—Heater Sensor
Temperature Prediction
BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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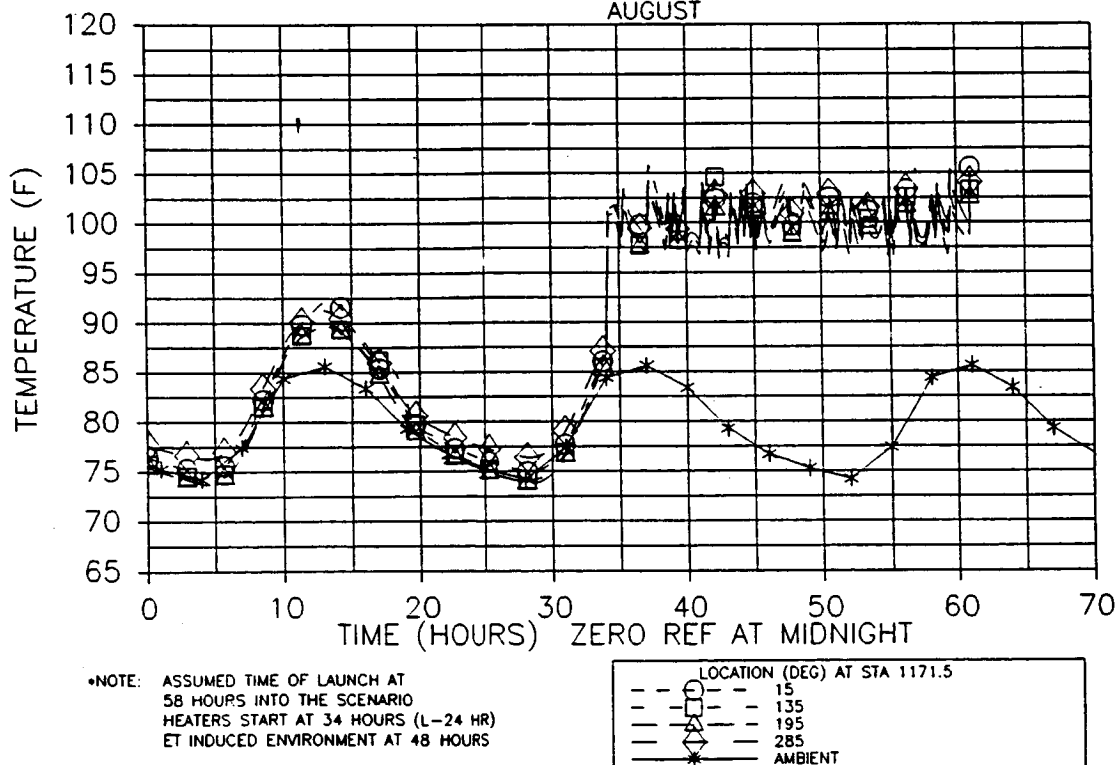


Figure 4.8-28. LH SRM Center Field Joint—Heater Sensor
Temperature Prediction

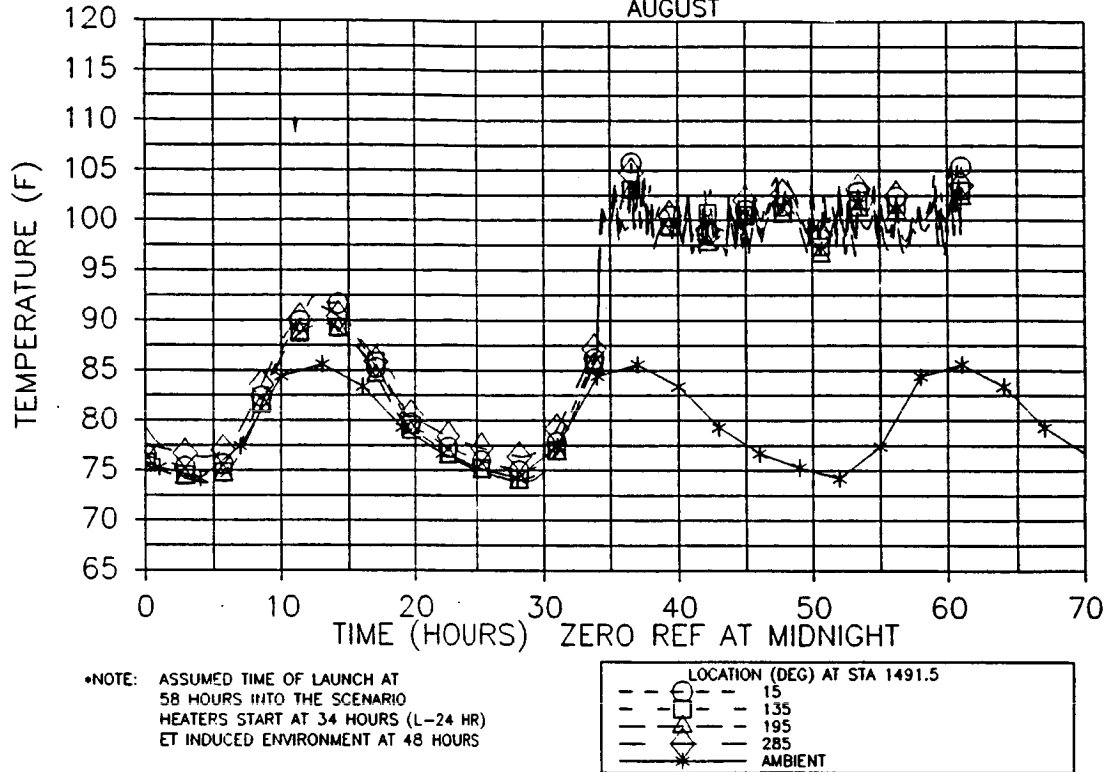


Figure 4.8-29. LH SRM Aft Field Joint—Heater Sensor Temperature Prediction

BASED ON KSC MONTHLY HISTORICAL ENVIRONMENTAL DATA
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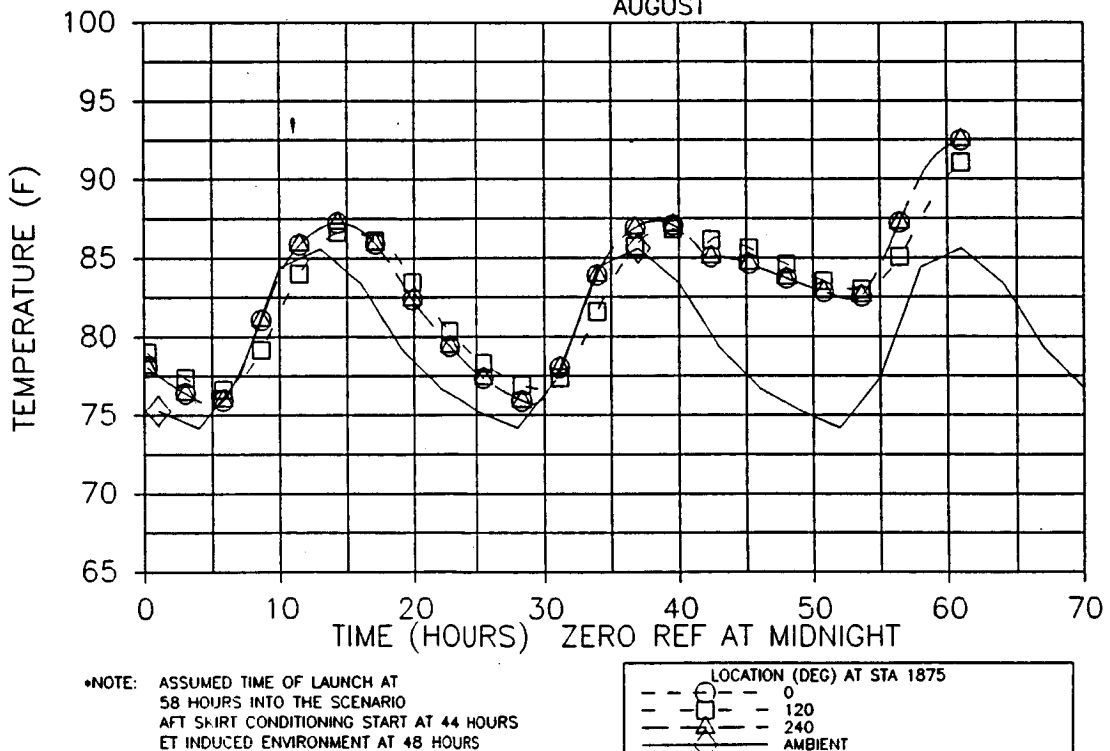


Figure 4.8-30. LH SRM Nozzle Region—GEI Sensor Temperature Prediction

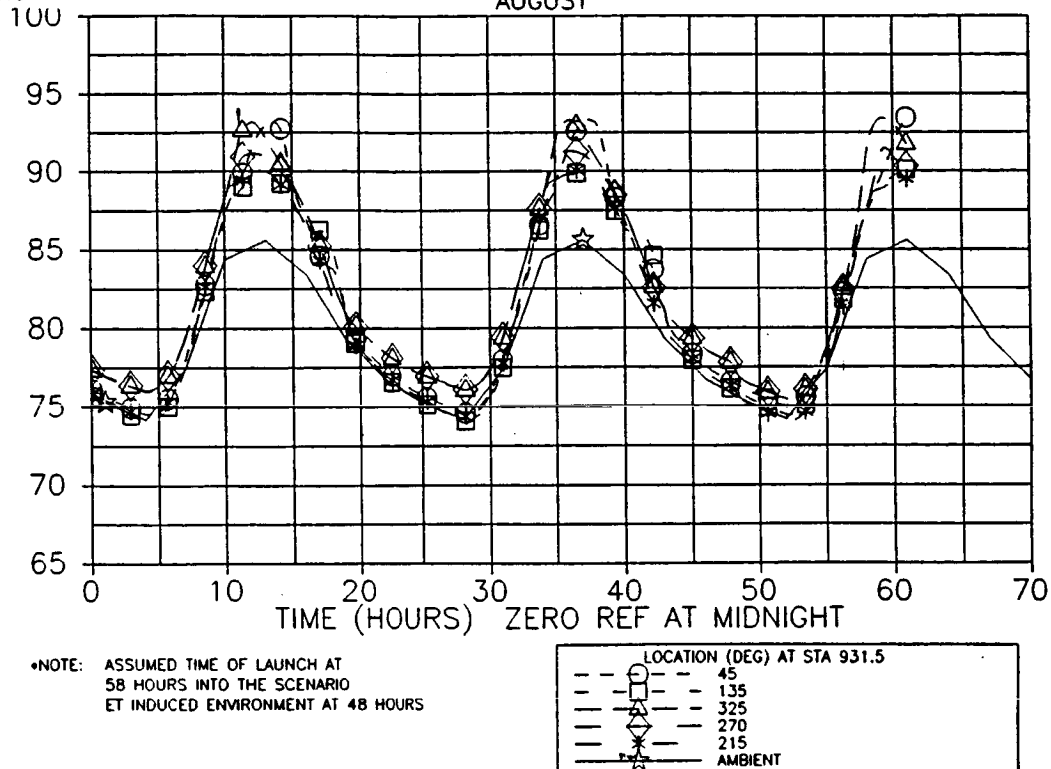


Figure 4.8-31. LH SRM Forward Case Acreage—GEI Sensor Temperature Prediction

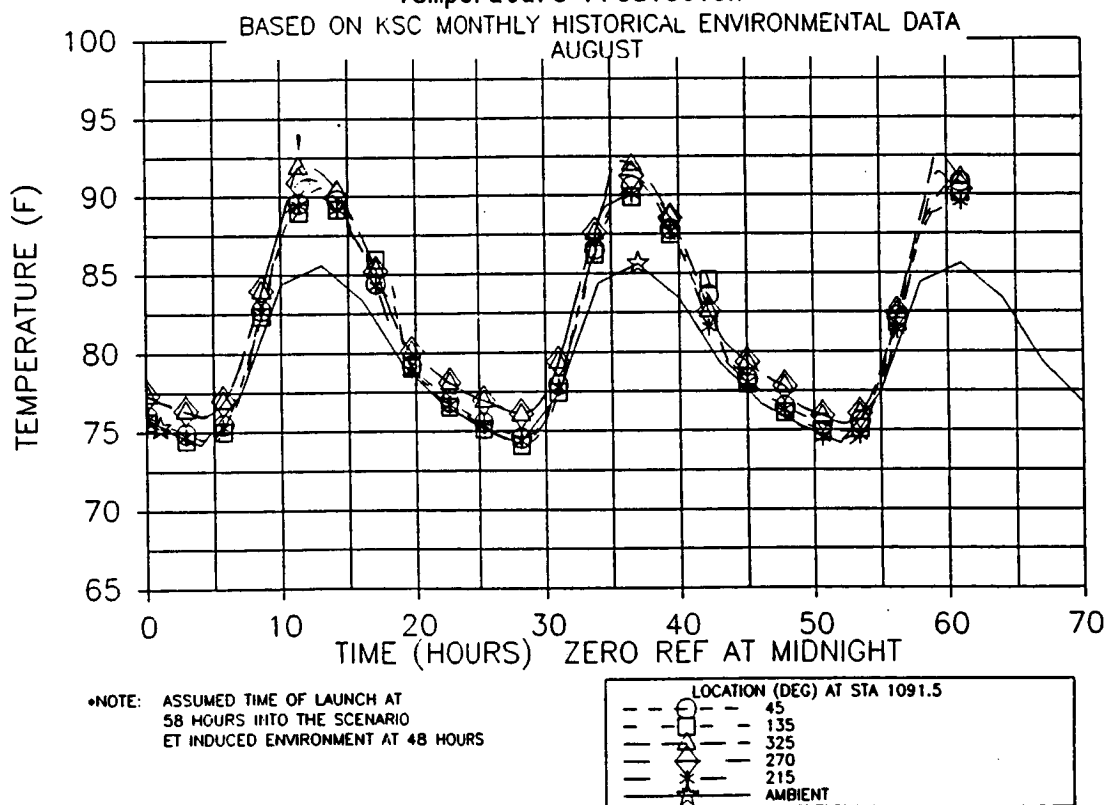


Figure 4.8-32. LH SRM Forward Center Case Acreage—GEI Sensor Temperature Prediction

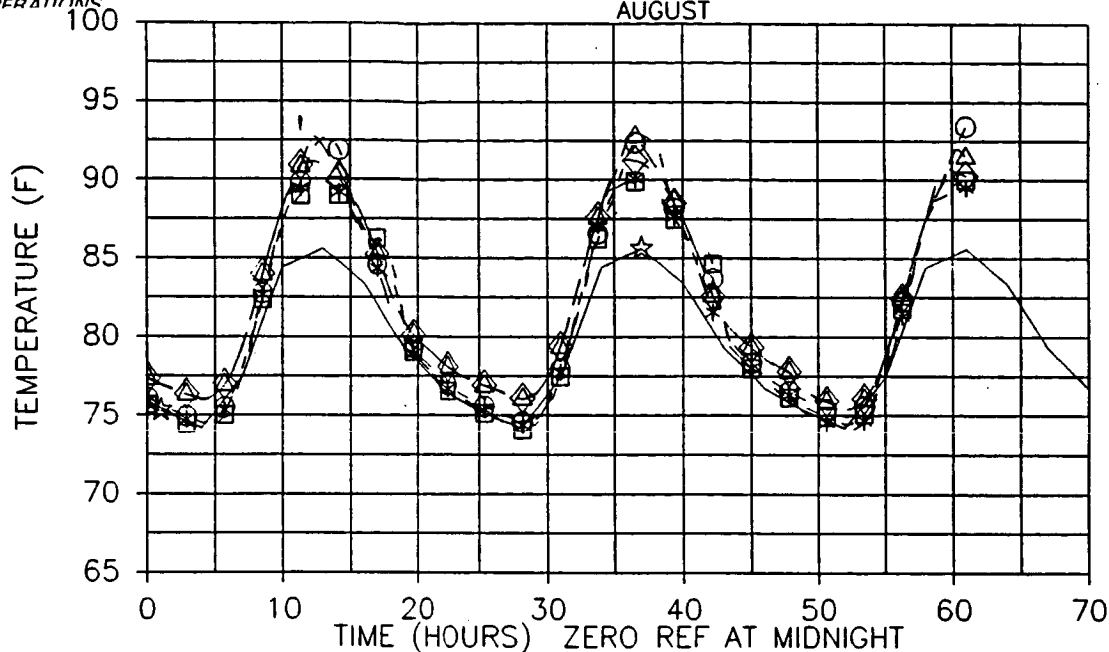


Figure 4.8-33. LH SRM Aft Center Case Acreage—GEI Sensor Temperature Prediction

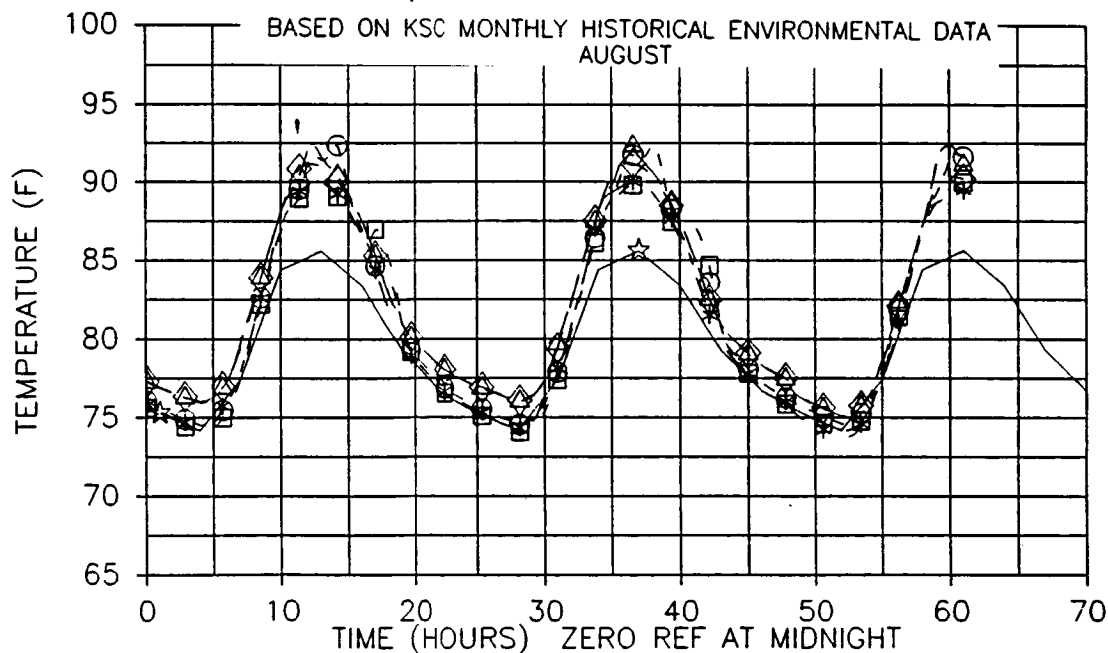


Figure 4.8-34. LH SRM Aft Case Acreage—GEI Sensor Temperature Prediction

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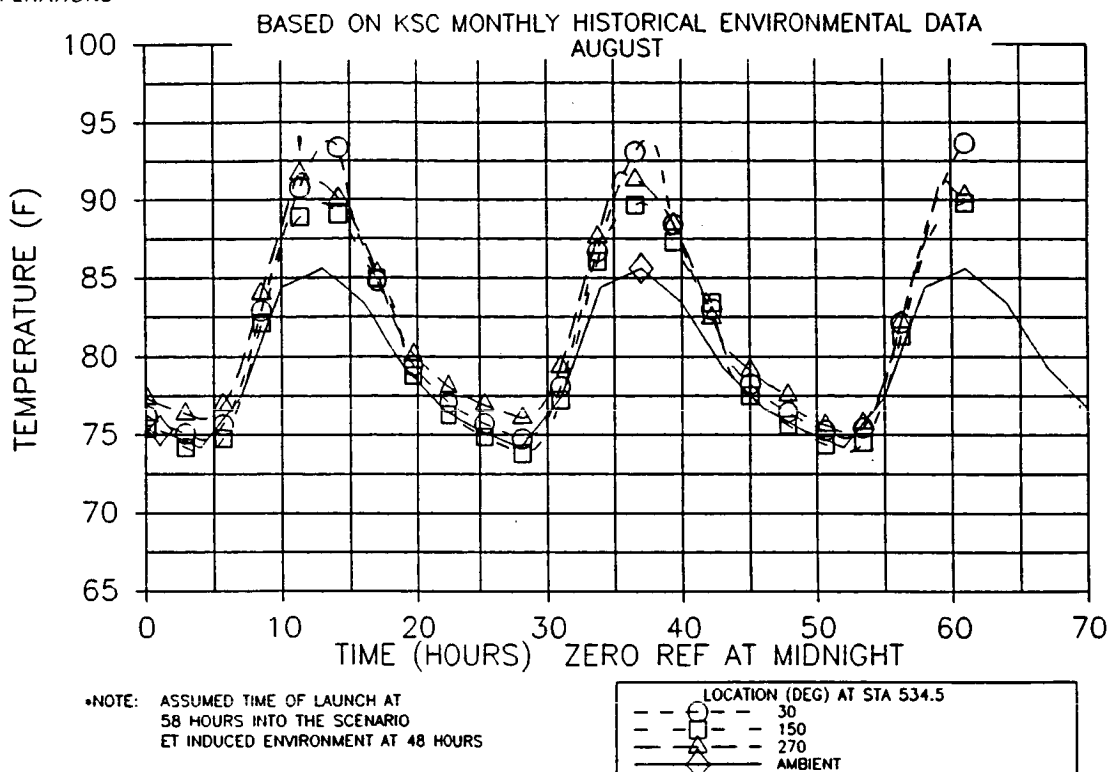


Figure 4.8-35. LH SRM Forward Dome Factory Joint—GEI Sensor Temperature Prediction

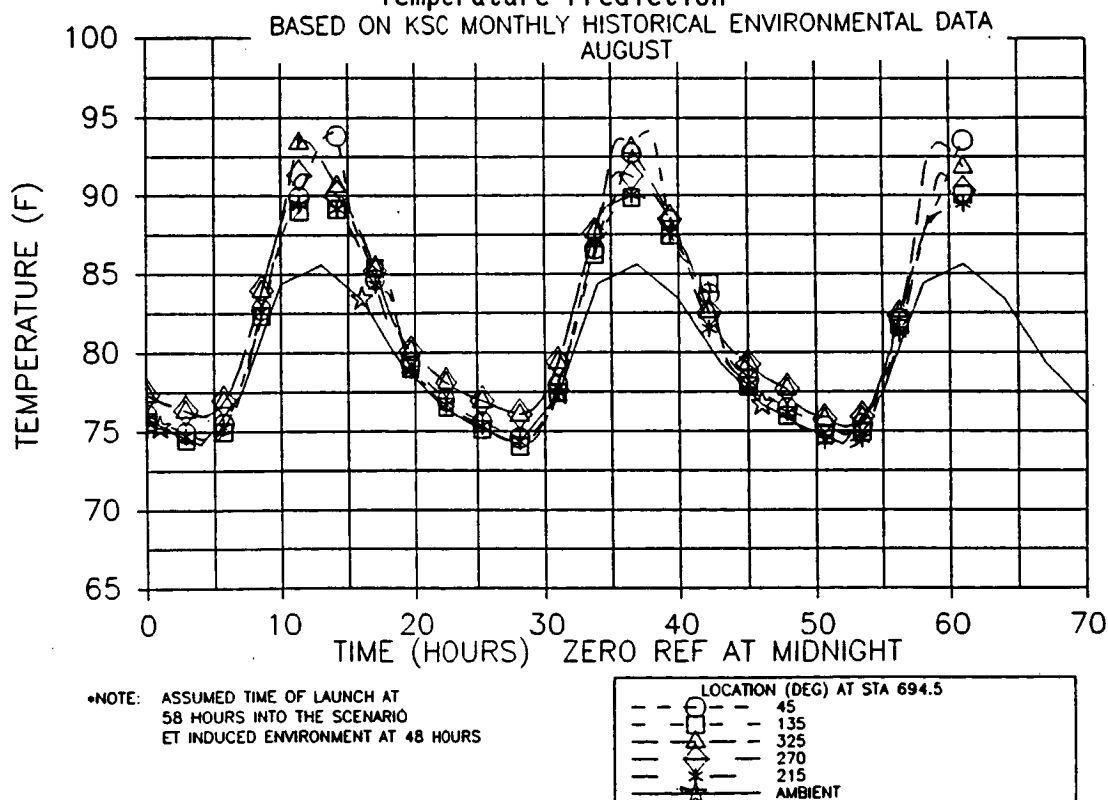


Figure 4.8-36. LH SRM Forward Factory Joint—GEI Sensor Temperature Prediction

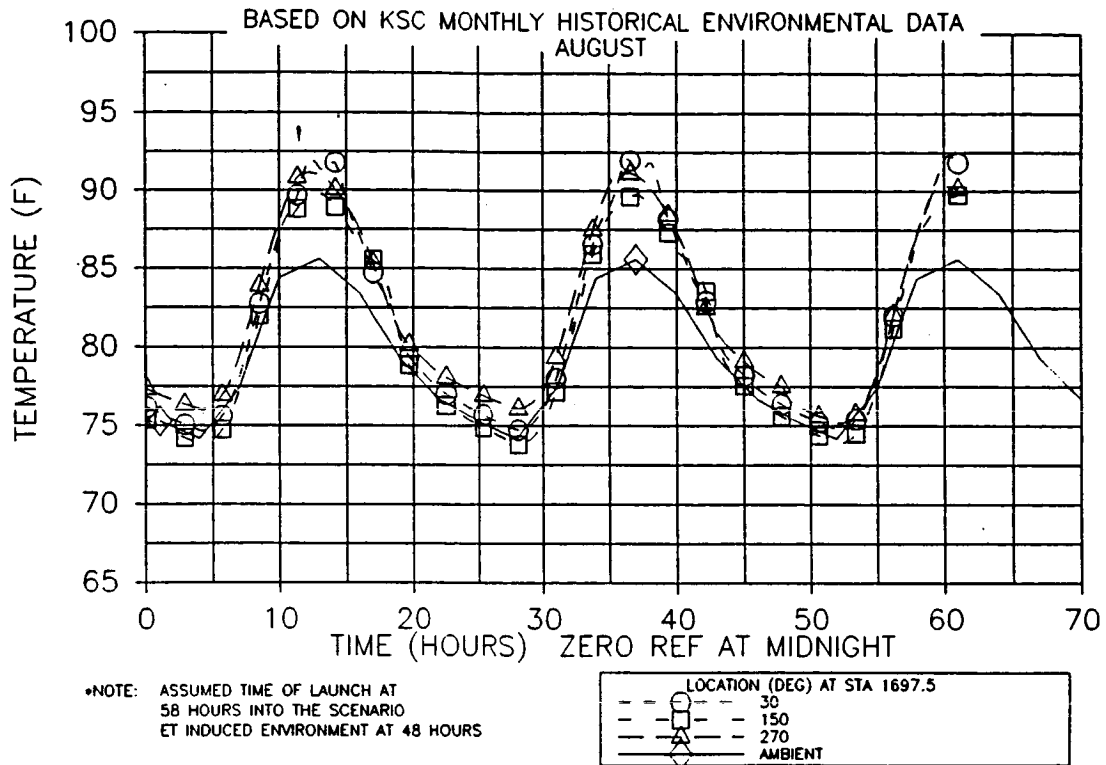


Figure 4.8-37. LH SRM Aft Factory Joint—GEI Sensor Temperature Prediction

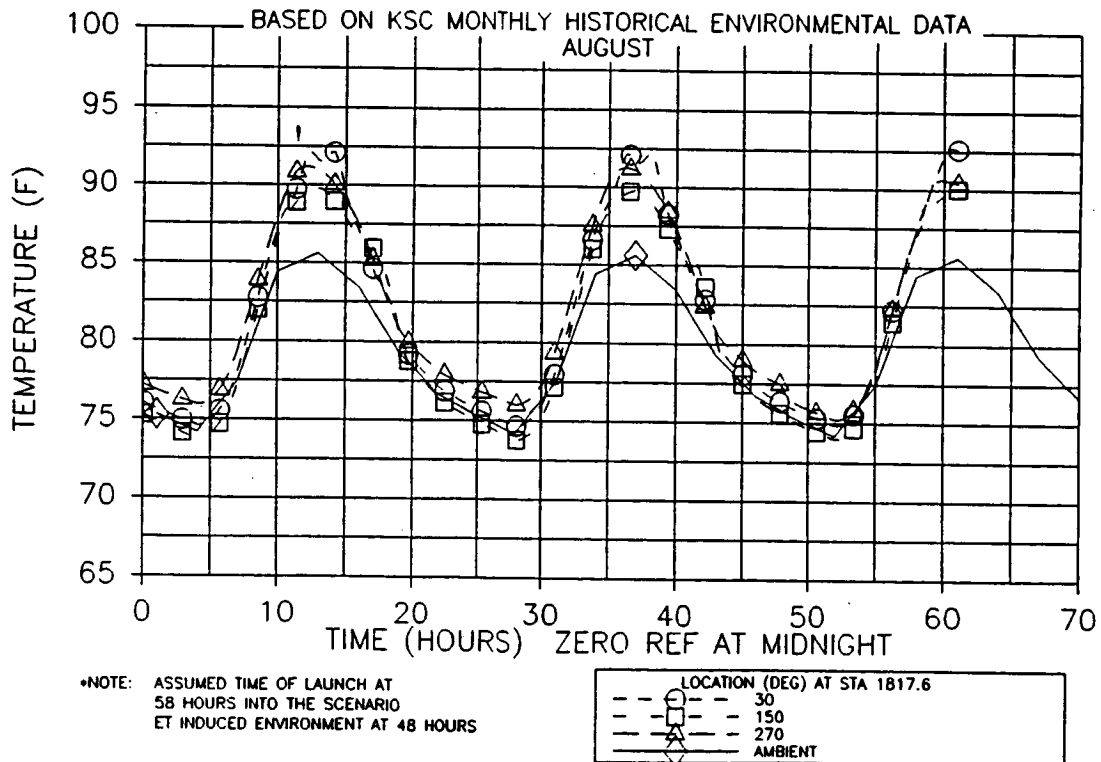


Figure 4.8-38. LH SRM Aft Dome Factory Joint—GEI Sensor Temperature Prediction

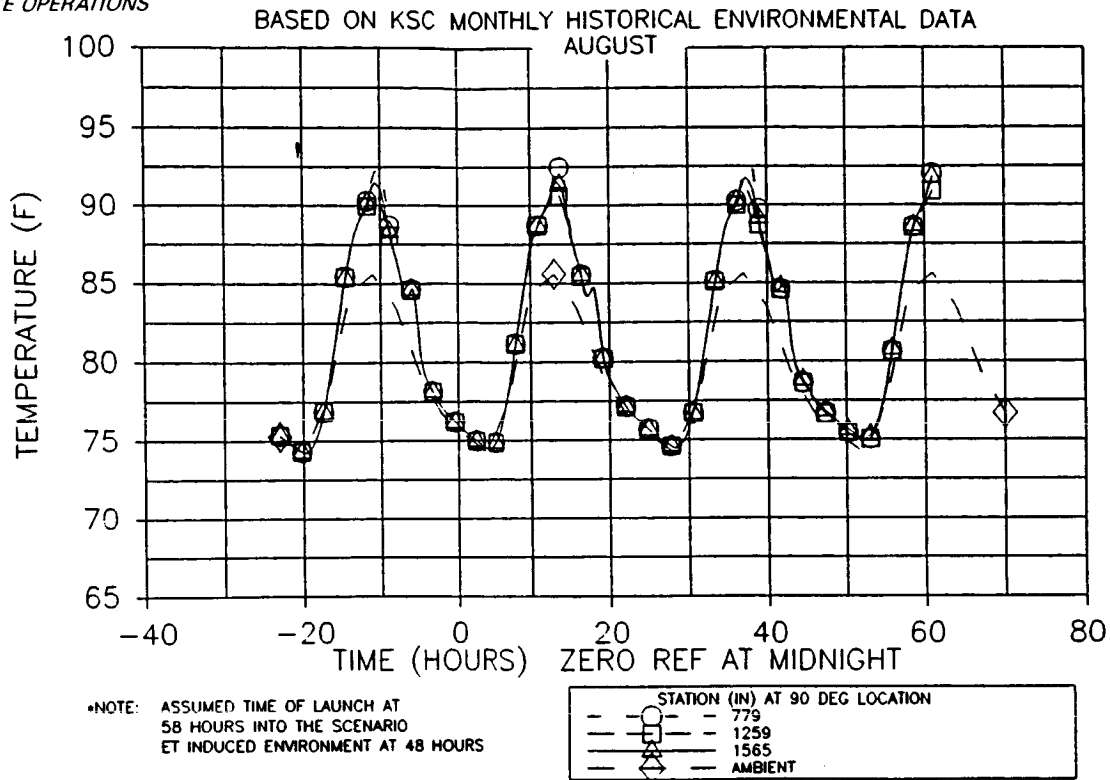


Figure 4.8-39. LH SRM Tunnel Bondline—GEI Sensor Temperature Prediction

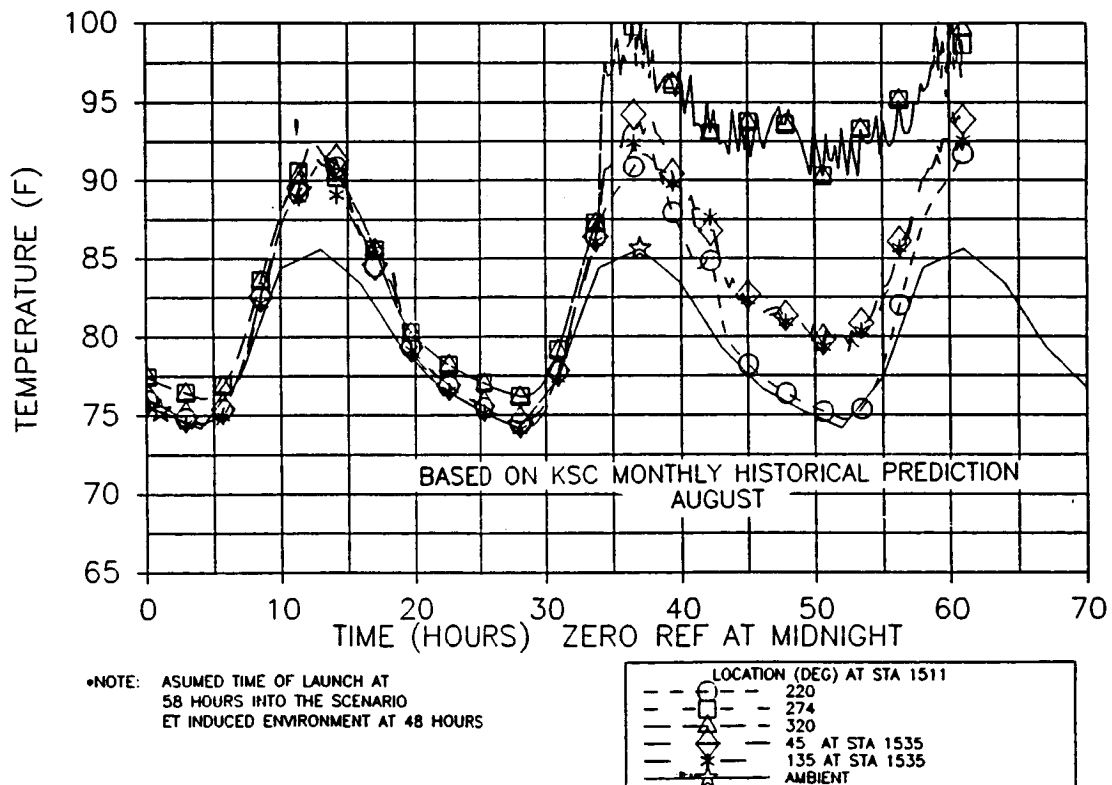


Figure 4.8-40. LH SRM ET Attach Region—GEI Sensor Temperature Prediction

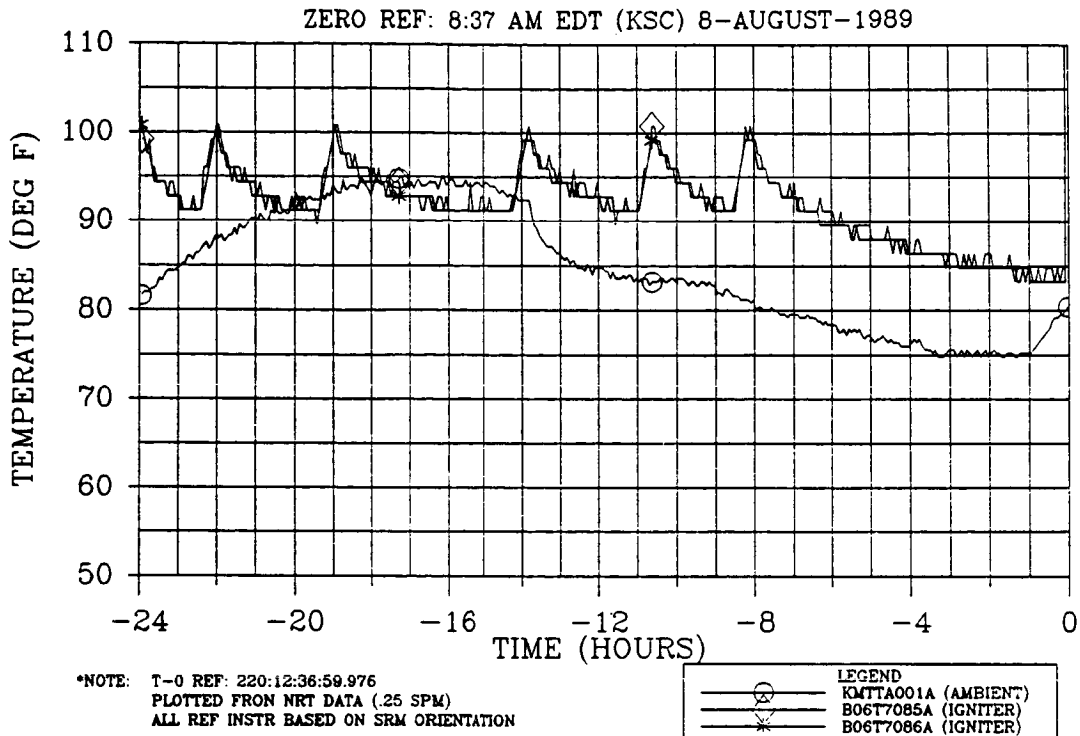


Figure 4.8-41. 360H005 (STS-28) Launch—24-hr LH SRM Igniter Joint Temperature Overlaid With Ambient

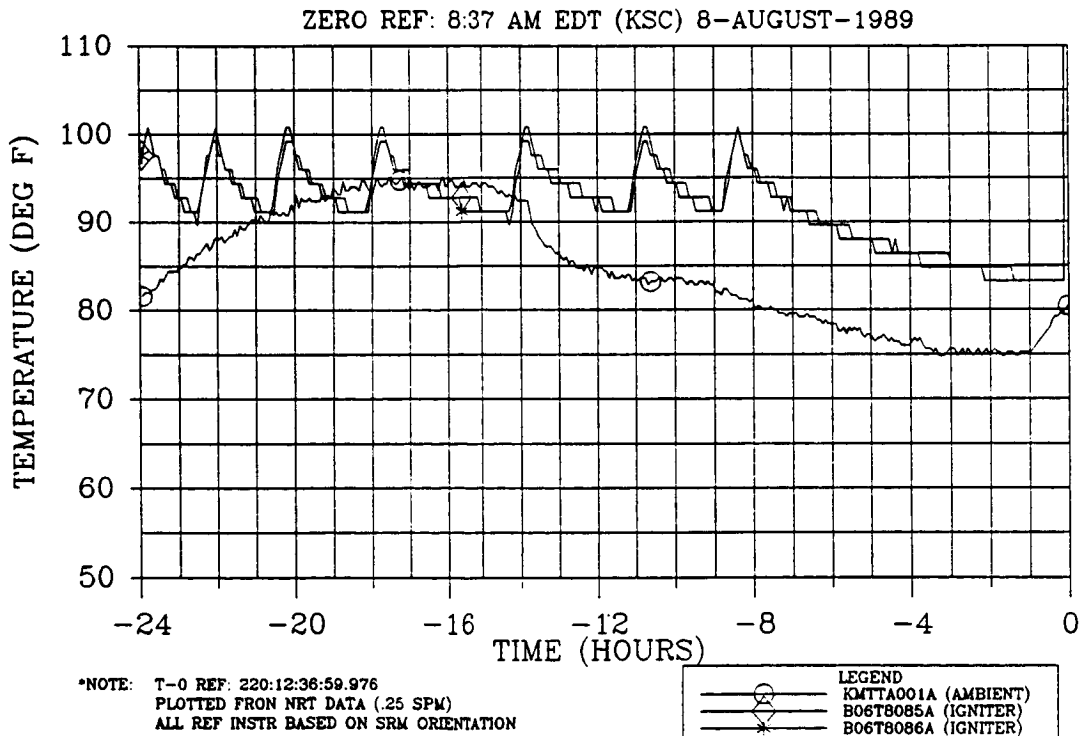


Figure 4.8-42. 360H005 (STS-28) Launch—24-hr RH SRM Igniter Joint Temperature Overlaid With Ambient

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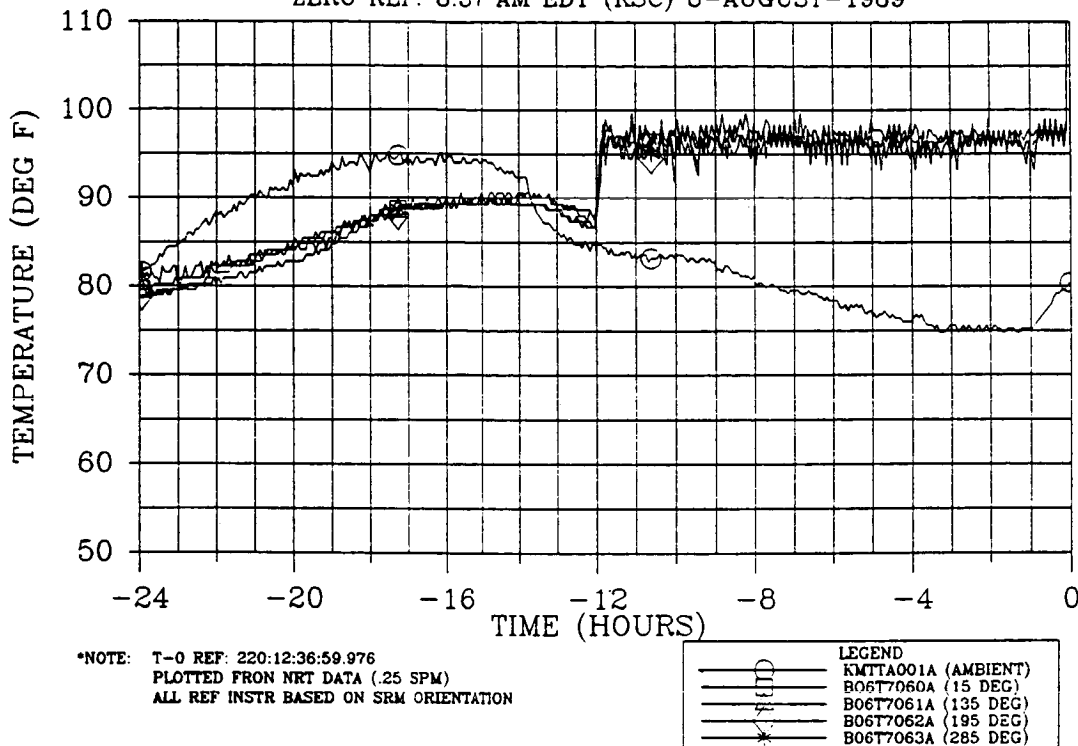


Figure 4.8-43. 360H005 (STS-28) Launch—24-hr LH SRM Forward Field Joint Temperature Overlaid With Ambient

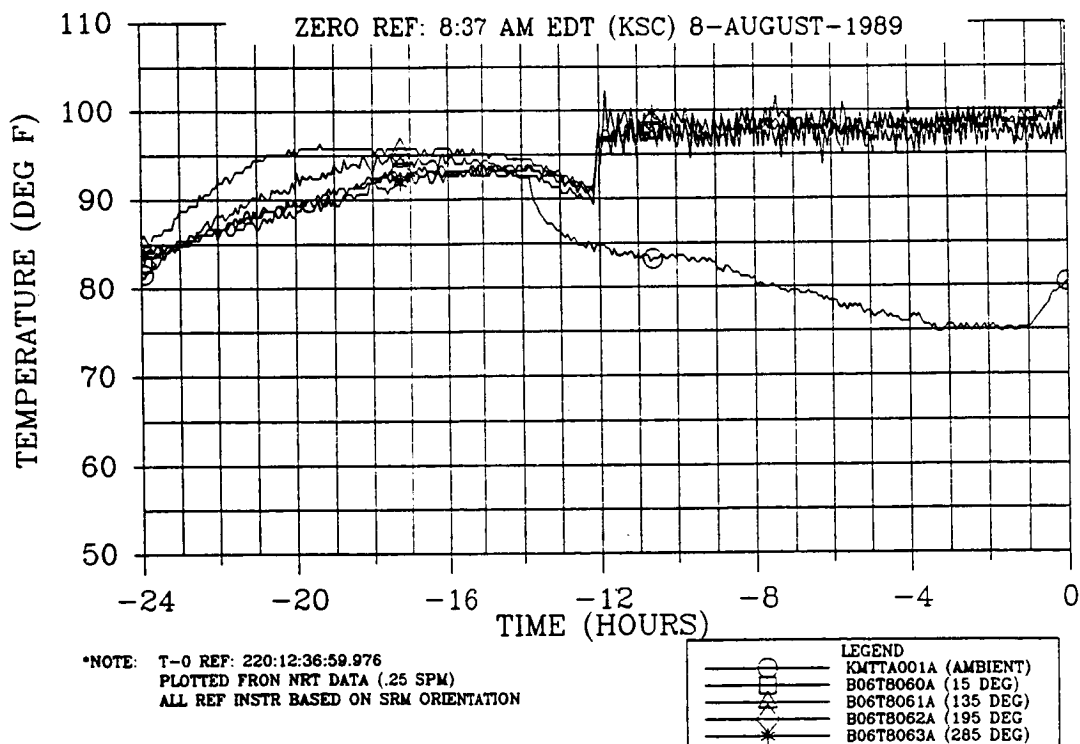


Figure 4.8-44. 360H005 (STS-28) Launch—24-hr RH SRM Forward Field Joint Temperature Overlaid With Ambient

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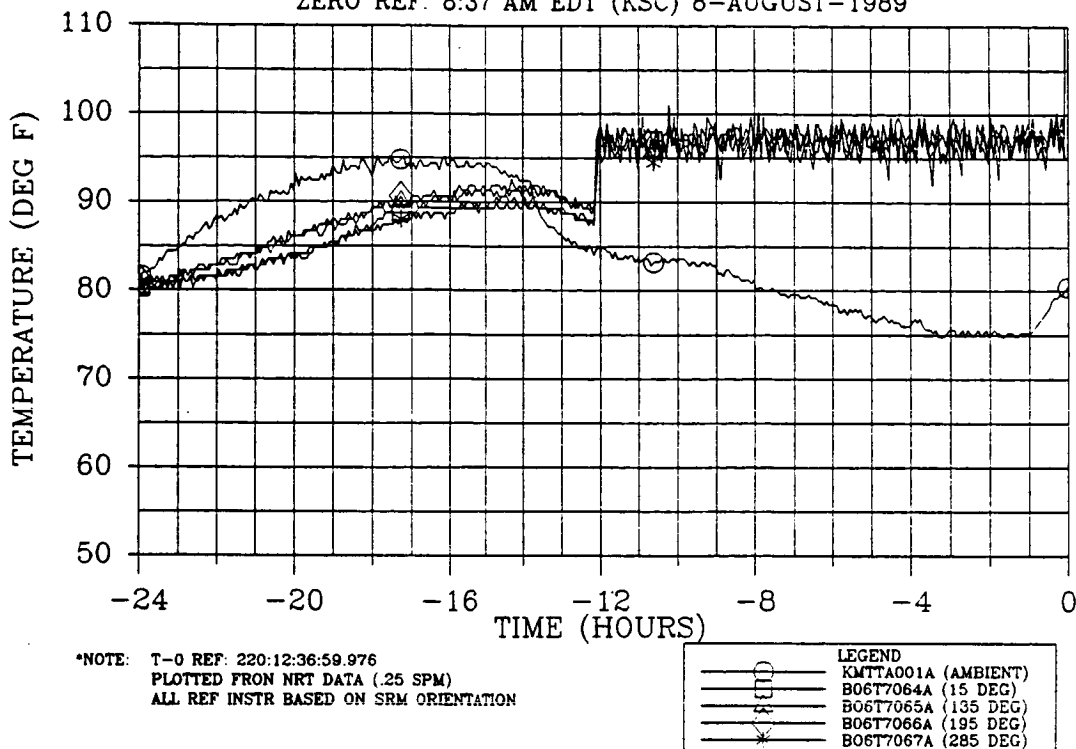


Figure 4.8-45. 360H005 (STS-28) Launch—24-hr LH SRM Center Field Joint Temperature Overlaid With Ambient

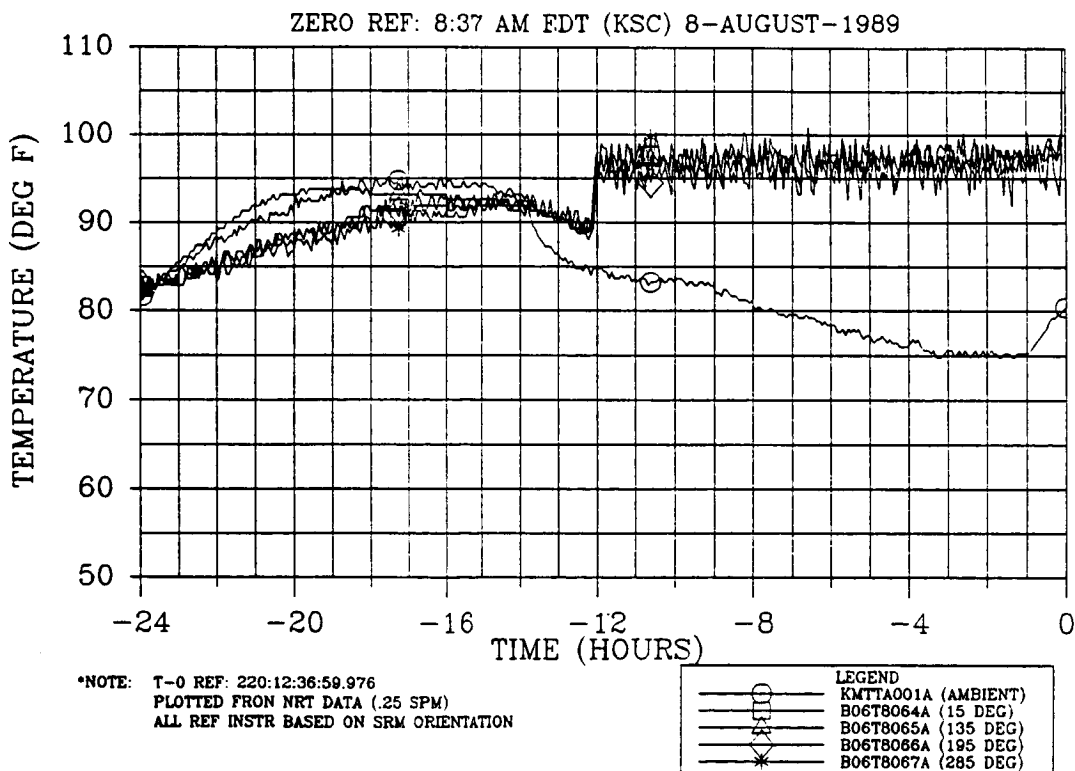


Figure 4.8-46. 360H005 (STS-28) Launch—24-hr RH SRM Center Field Joint Temperature Overlaid With Ambient

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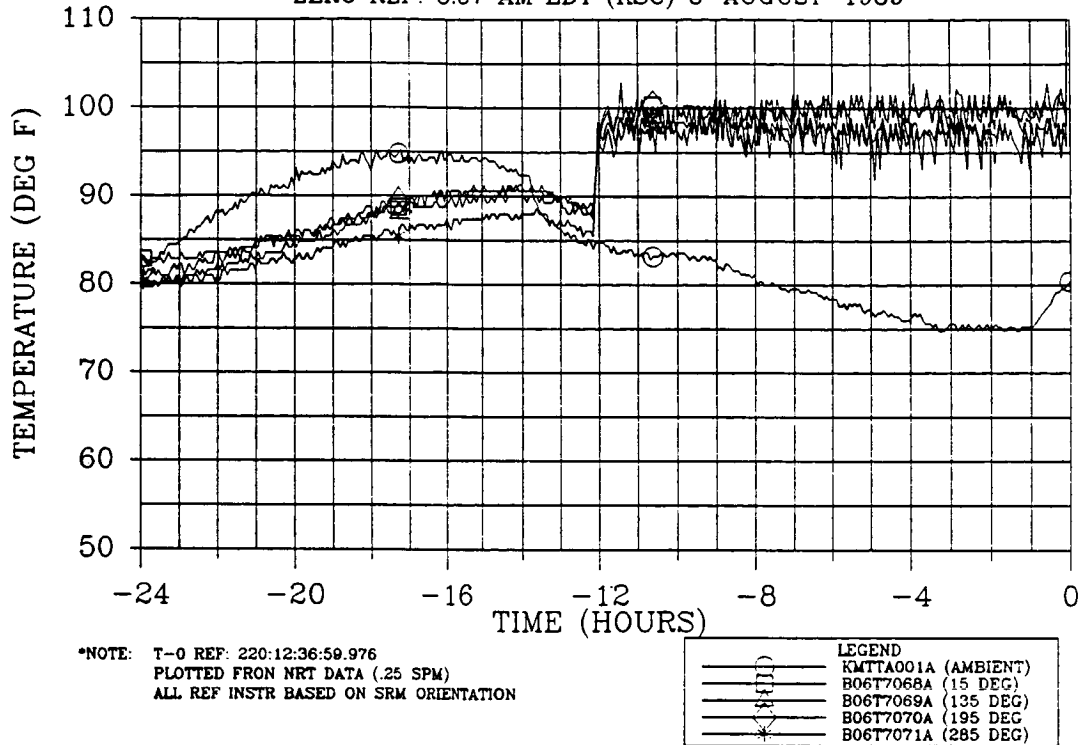


Figure 4.8-47. 360H005 (STS-28) Launch—24-hr LH SRM Aft Field Joint Temperature Overlaid With Ambient

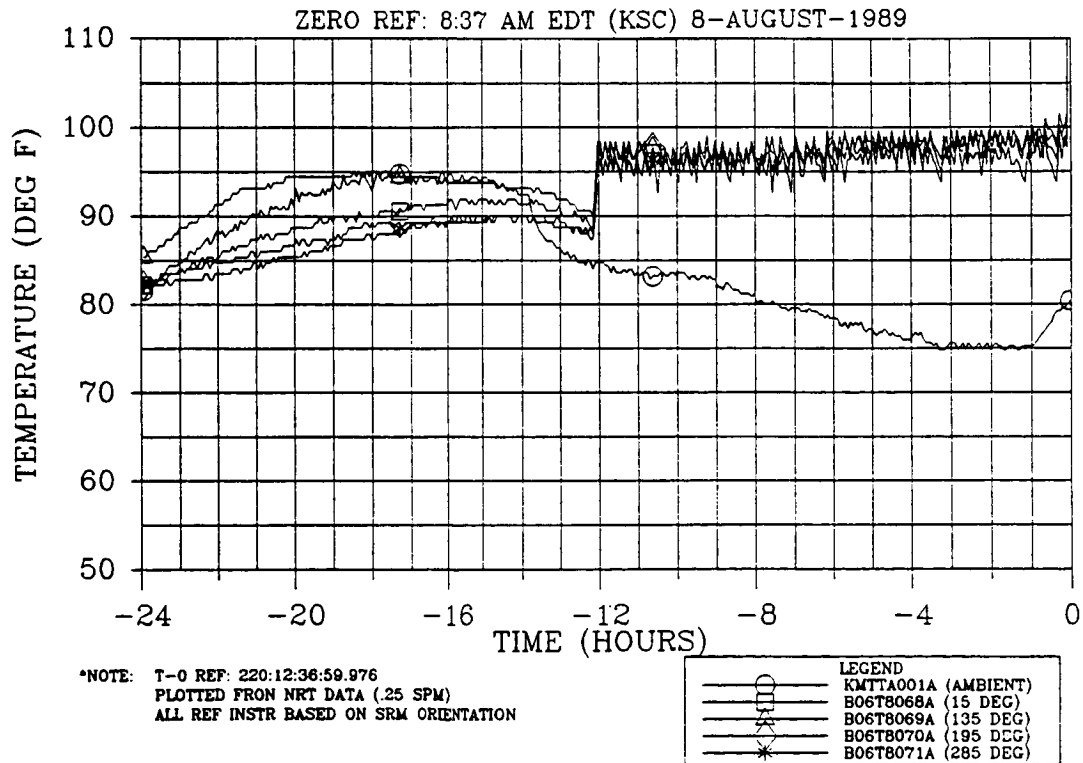


Figure 4.8-48. 360H005 (STS-28) Launch—24-hr RH SRM Aft Field Joint Temperature Overlaid With Ambient

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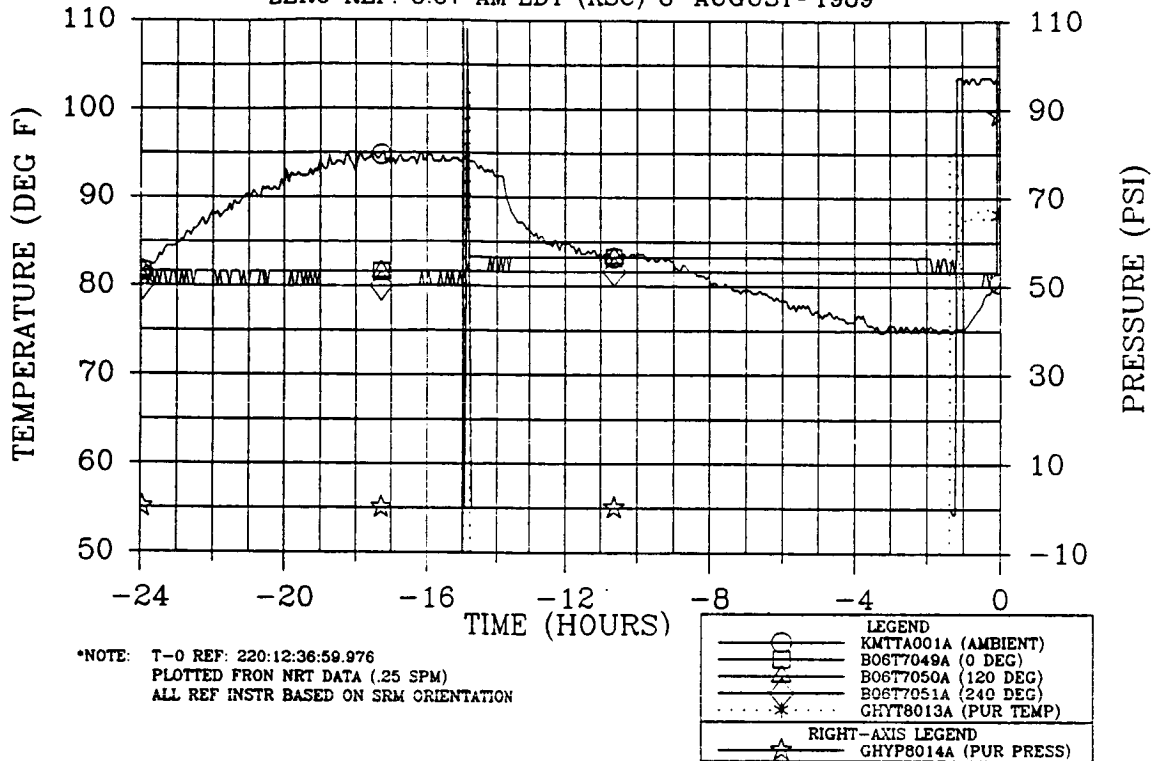


Figure 4.8-49. 360H005 (STS-28) Launch—24-hr LH SRM Case-to-Nozzle Joint Temperature Overlaid With Ambient

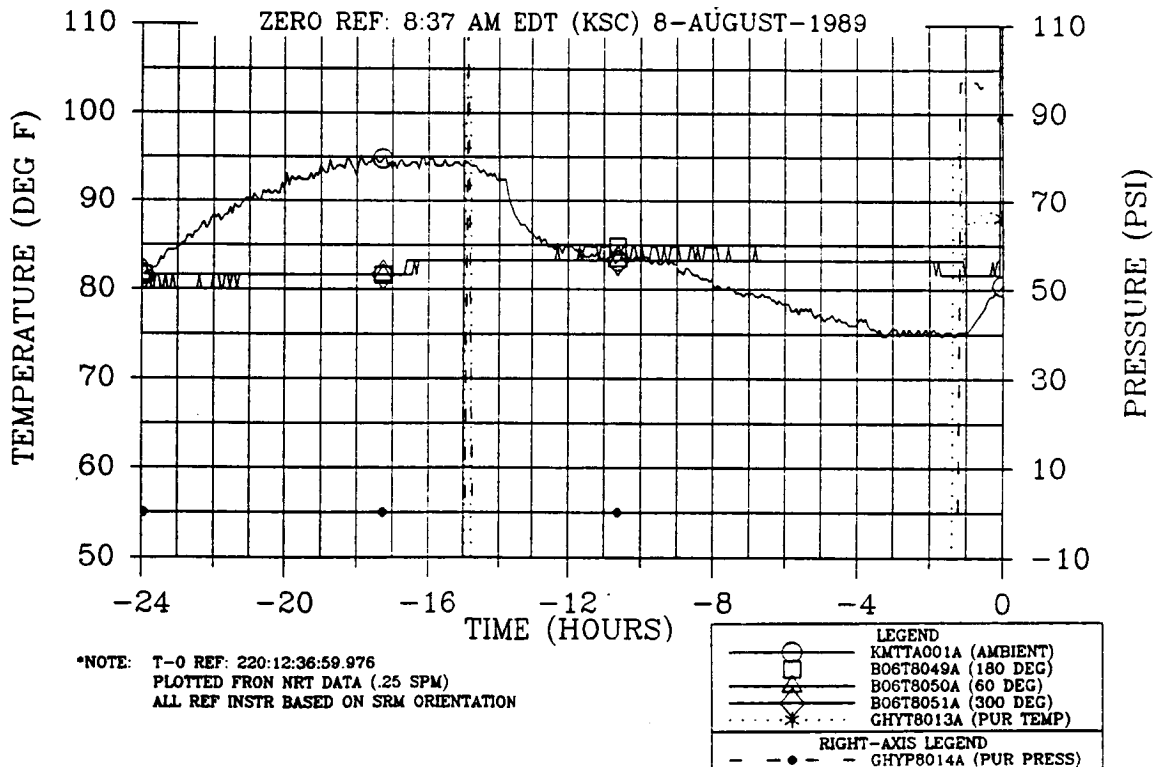


Figure 4.8-50. 360H005 (STS-28) Launch—24-hr RH SRM Case-to-Nozzle Joint Temperature Overlaid With Ambient

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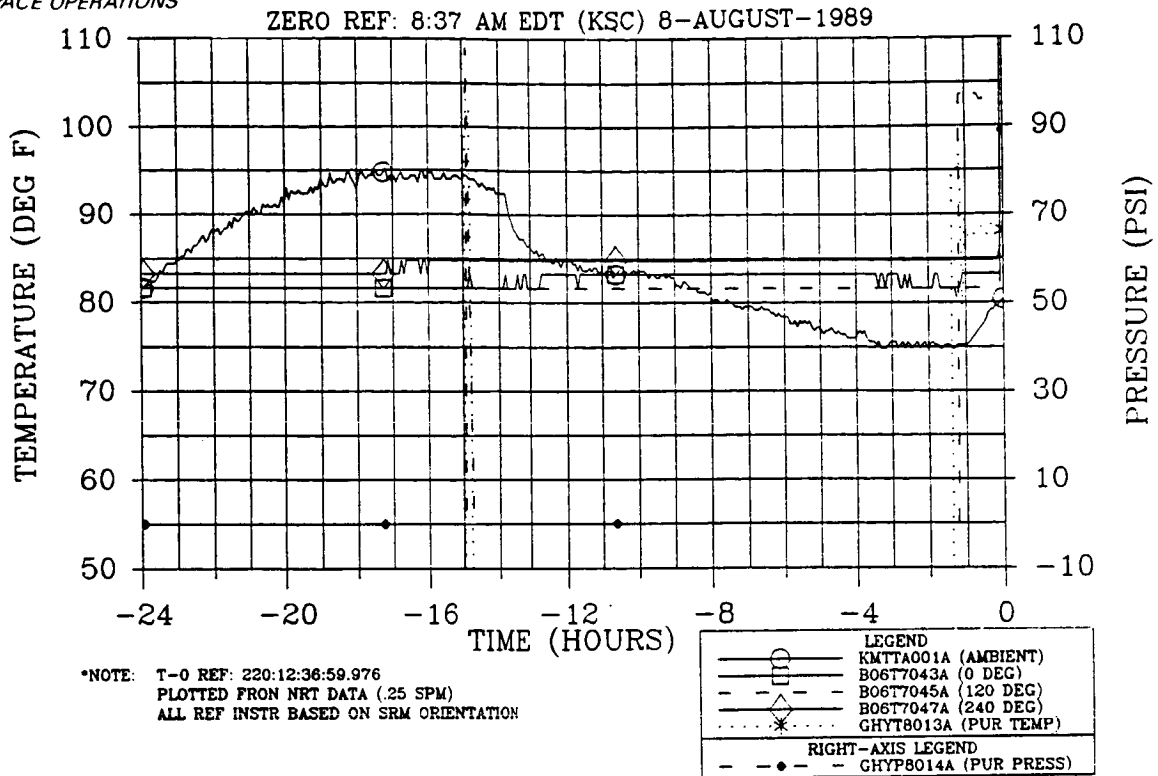


Figure 4.8-51. 360H005 (STS-28) Launch—24-hr LH SRM Flex Bearing Aft End Ring Temperature Overlaid With Ambient

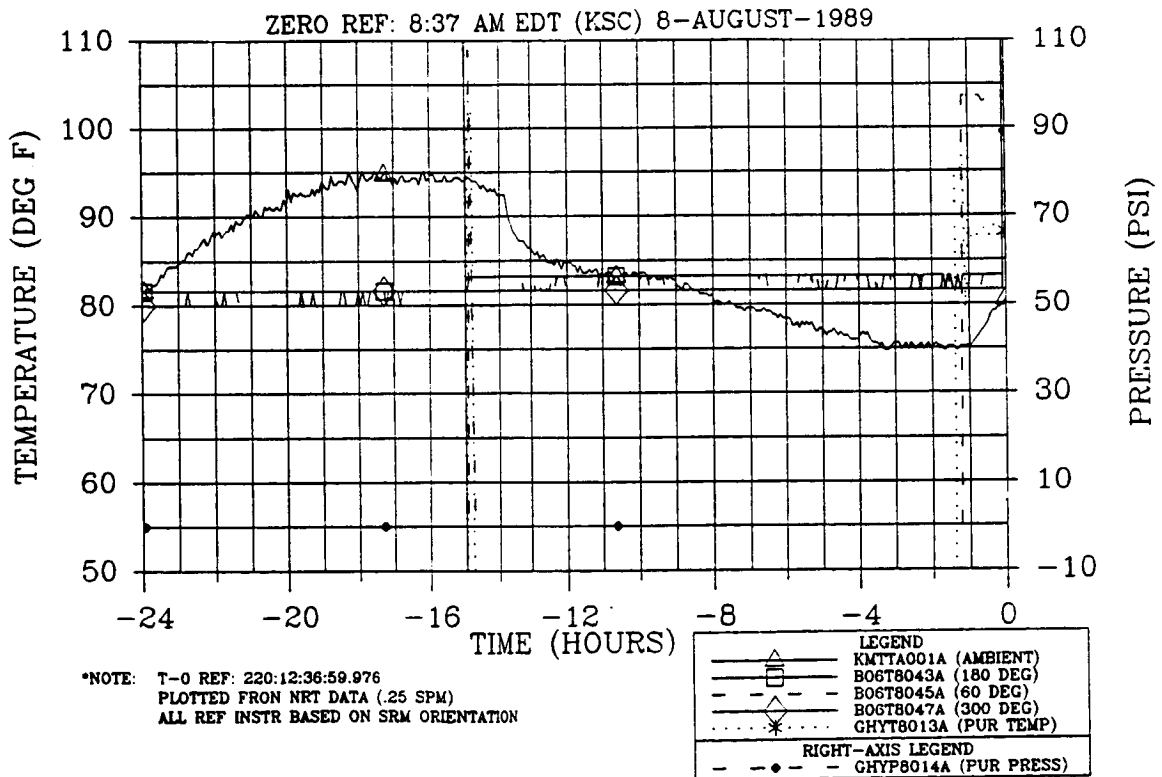


Figure 4.8-52. 360H005 (STS-28) Launch—24-hr RH SRM Flex Bearing Aft End Ring Temperature Overlaid With Ambient

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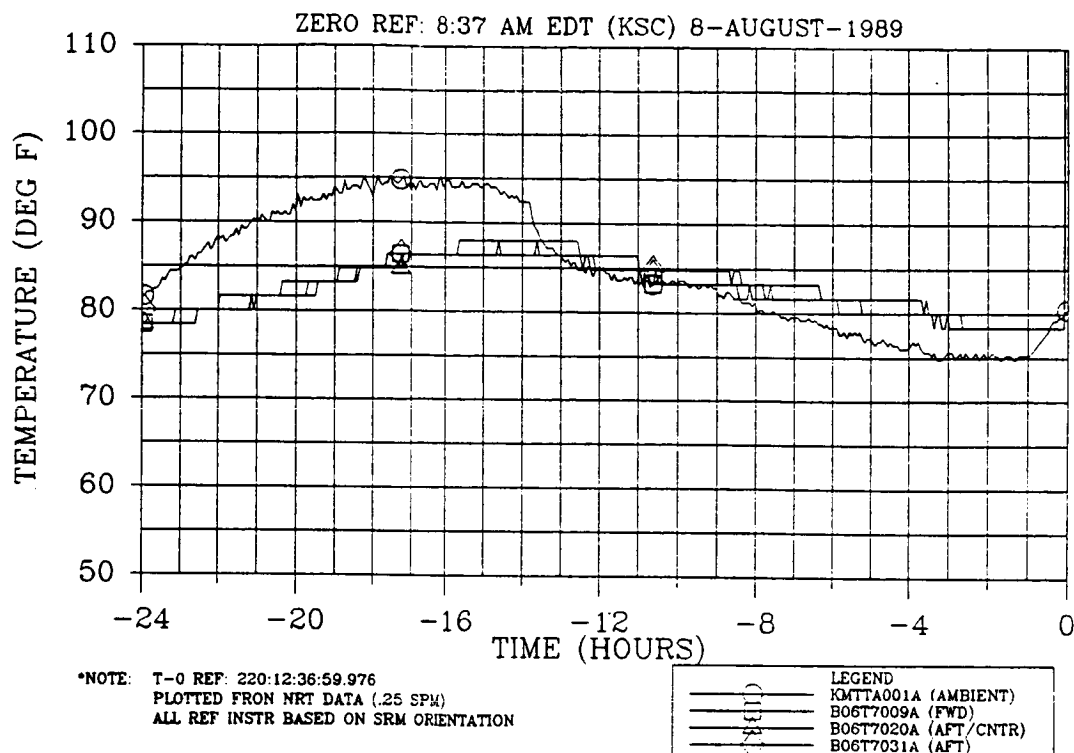


Figure 4.8-53. 360H005 (STS-28) Launch—24-hr LH SRM Tunnel Bondline Temperature Overlaid With Ambient

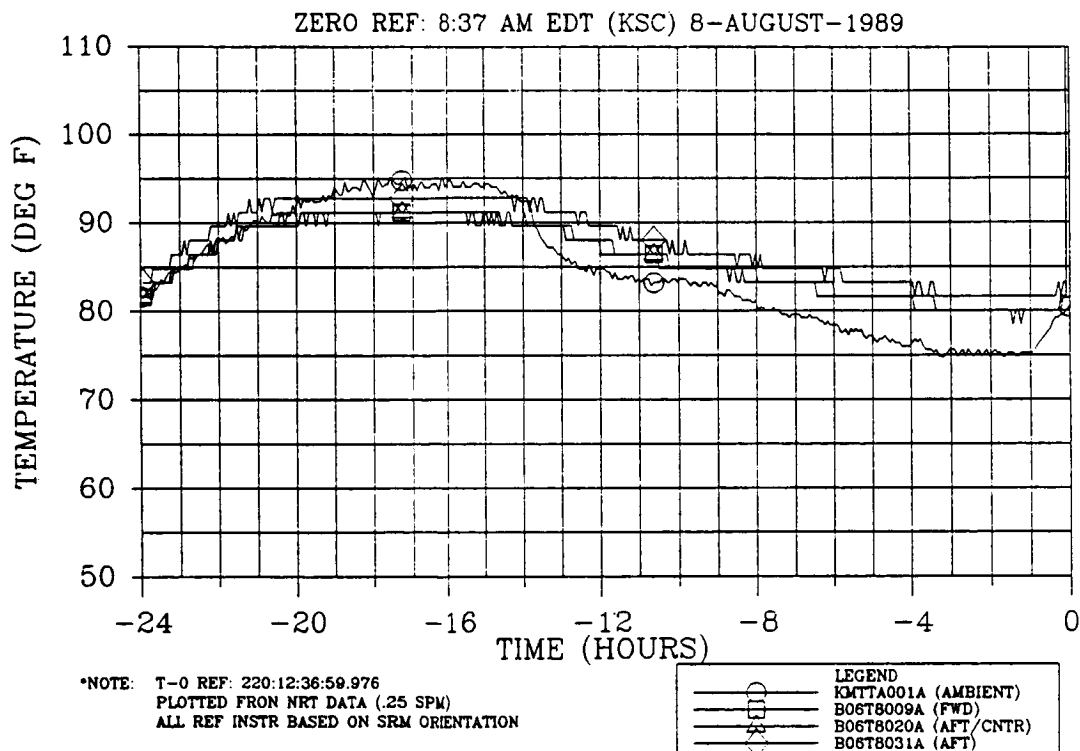


Figure 4.8-54. 360H005 (STS-28) Launch—24-hr RH SRM Tunnel Bondline Temperature Overlaid With Ambient

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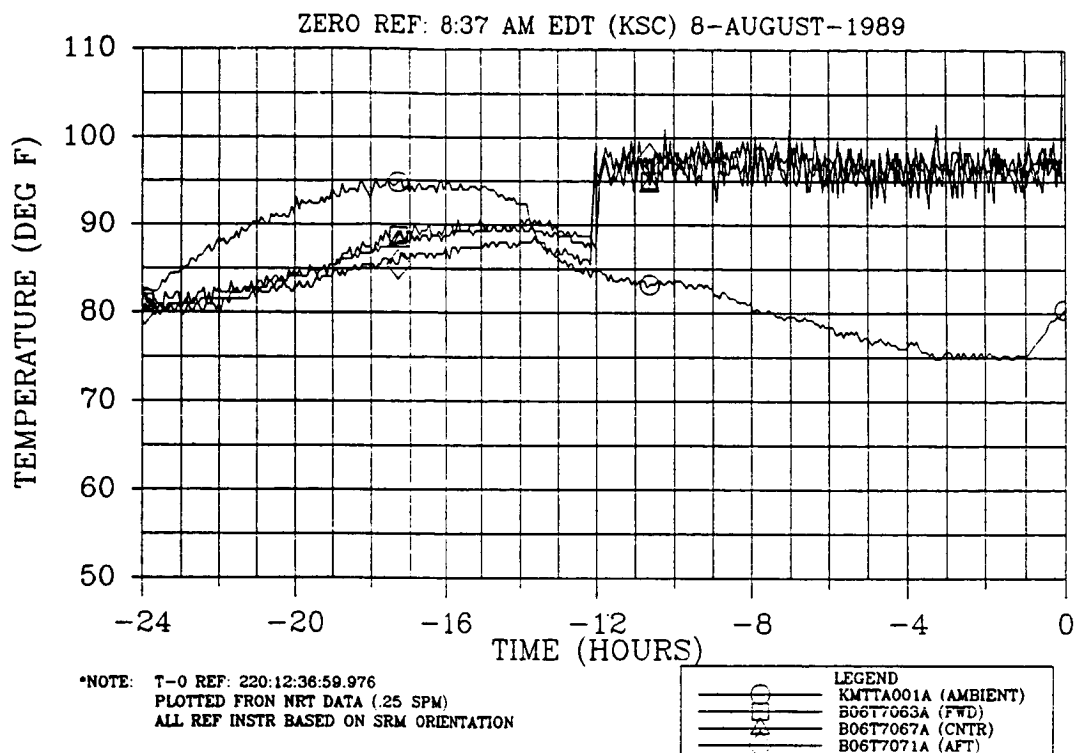


Figure 4.8-55. 360H005 (STS-28) Launch—24-hr LH SRM Field Joint Temperature at 285-deg Location Overlaid With Ambient

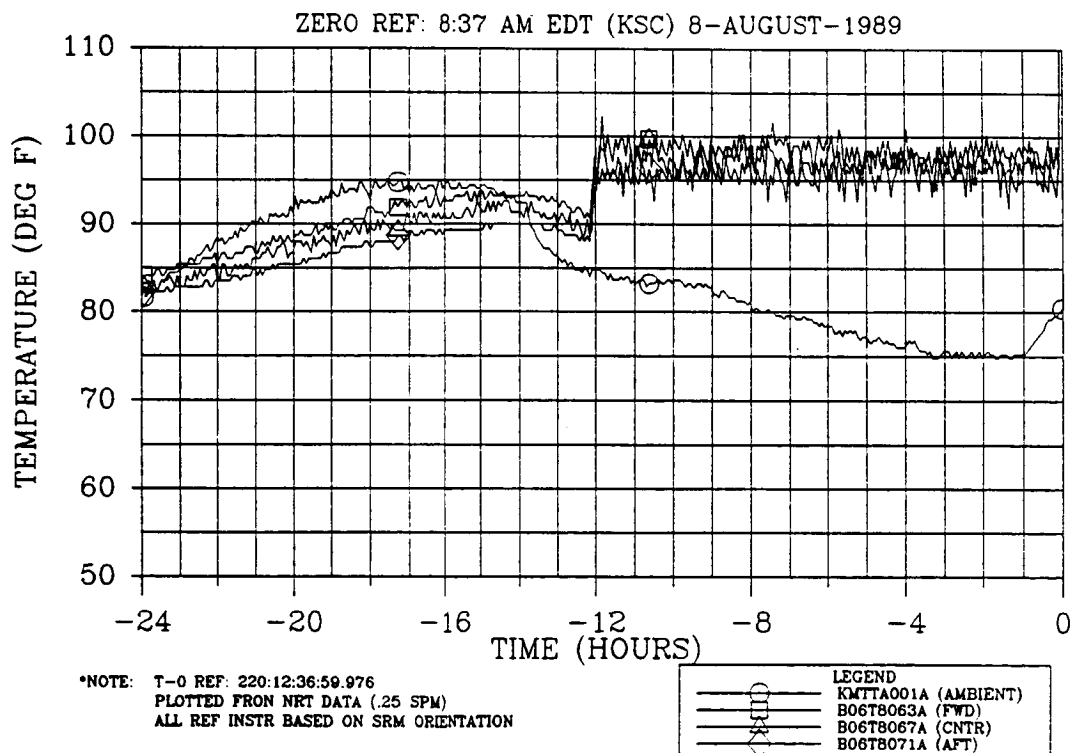


Figure 4.8-56. 360H005 (STS-28) Launch—24-hr RH SRM Field Joint Temperature at 285-deg Location Overlaid With Ambient

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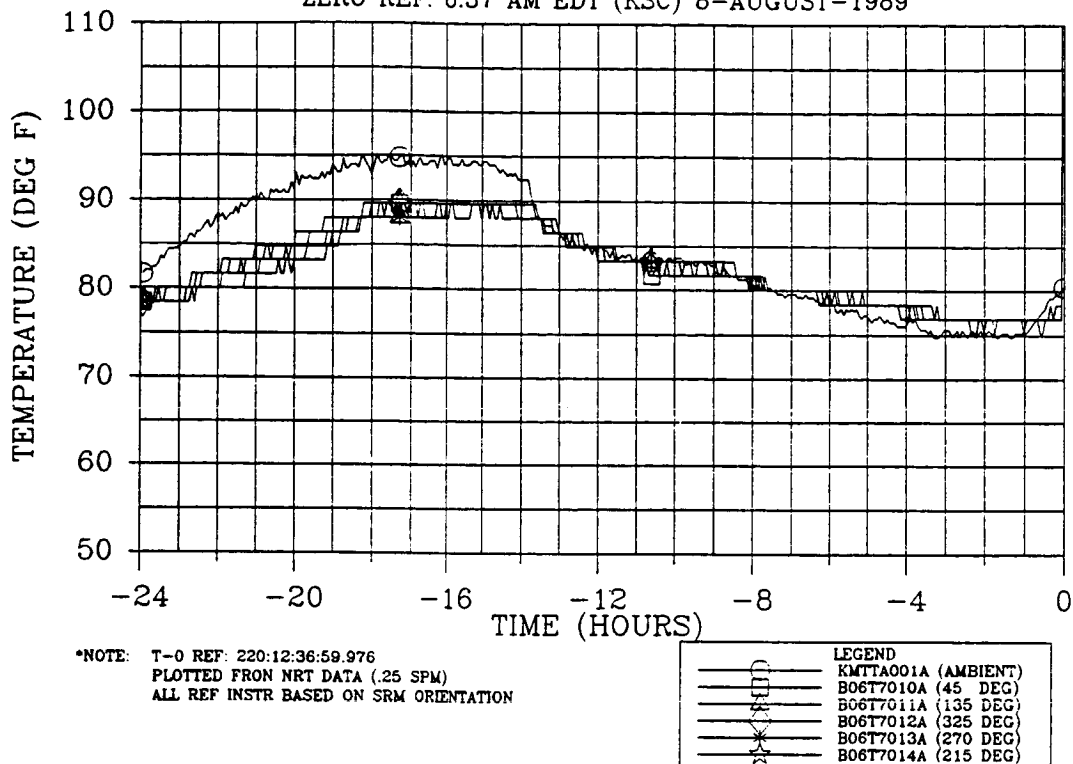


Figure 4.8-57. 360H005 (STS-28) Launch—24-hr LH SRM Case Acreage Temperature at Station 931.5 Overlaid With Ambient

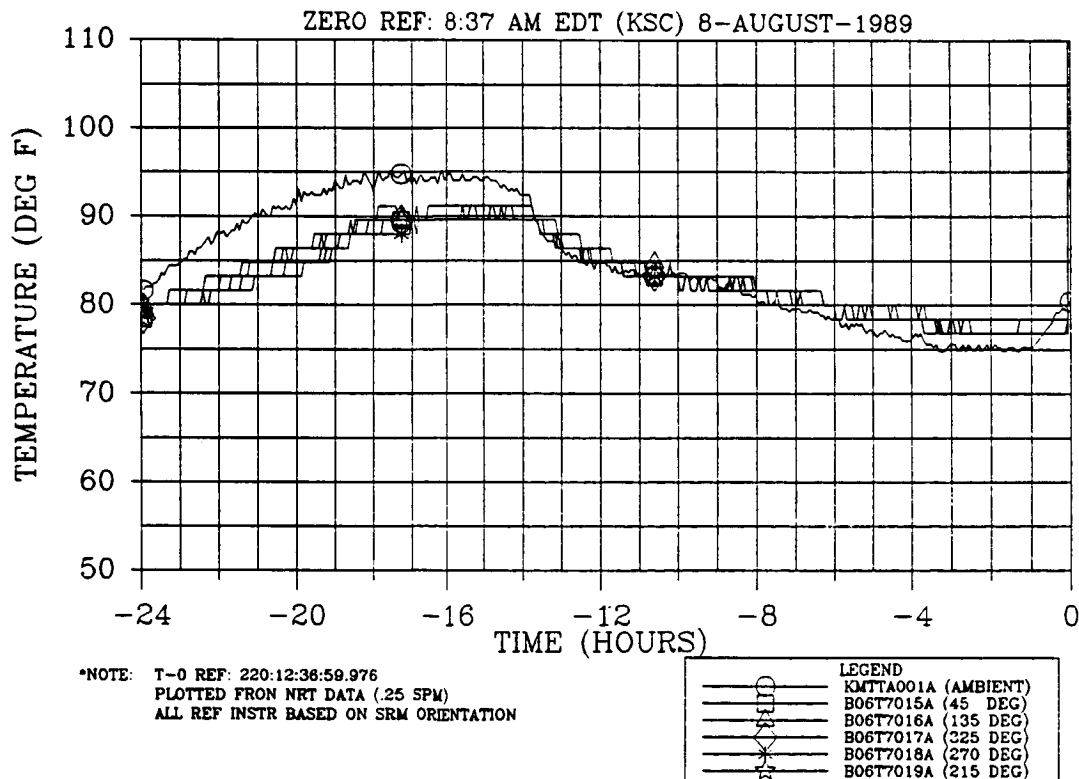


Figure 4.8-58. 360H005 (STS-28) Launch—24-hr LH SRM Case Acreage Temperature at Station 1091.5 Overlaid With Ambient

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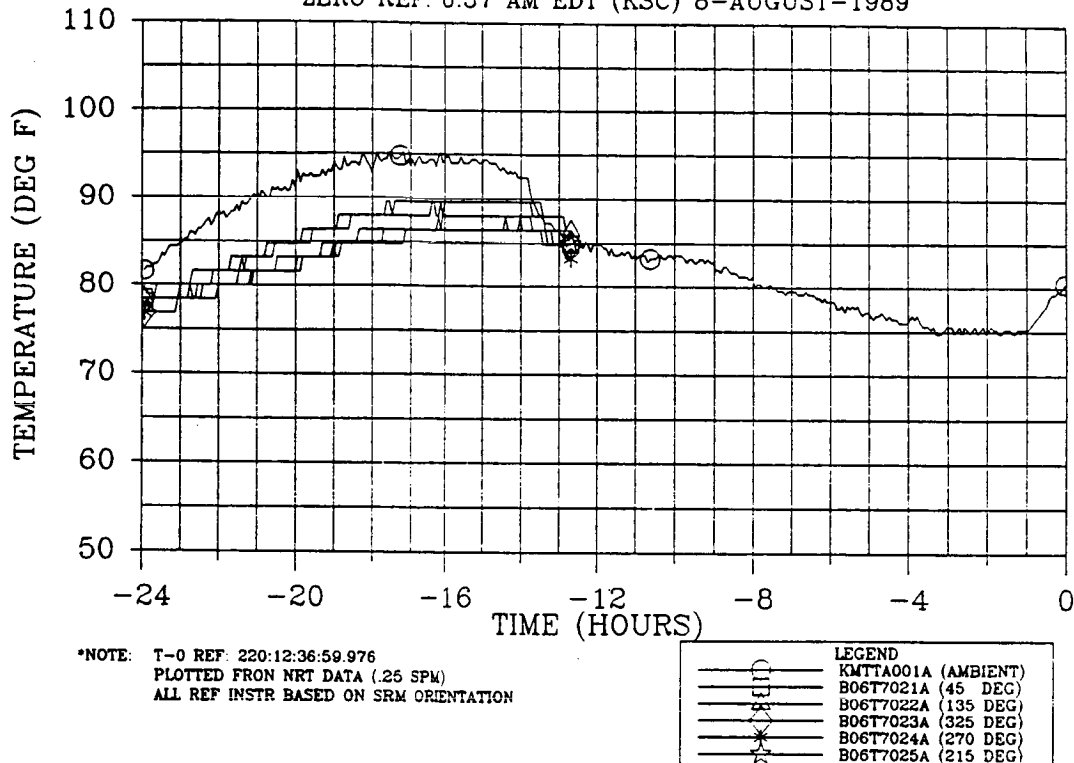


Figure 4.8-59. 360H005 (STS-28) Launch—24-hr LH SRM Case Acreage Temperature at Station 1411.5 Overlaid With Ambient

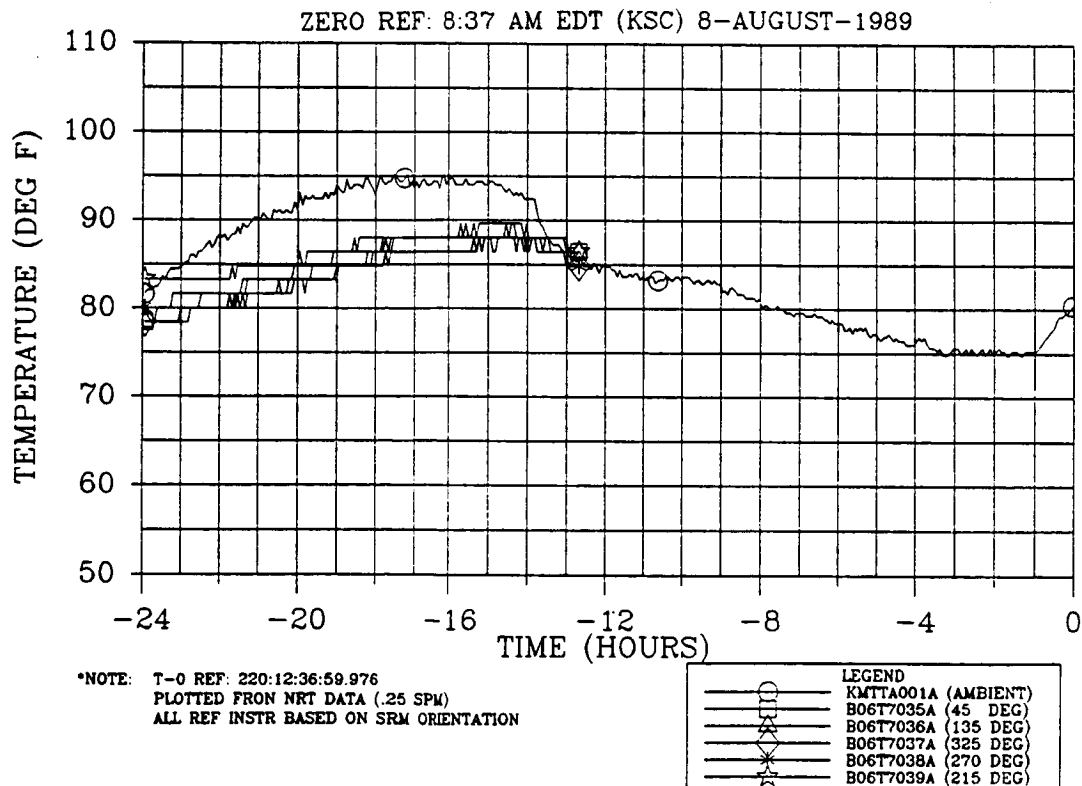


Figure 4.8-60. 360H005 (STS-28) Launch—24-hr LH SRM Case Acreage Temperature at Station 1751.5 Overlaid With Ambient

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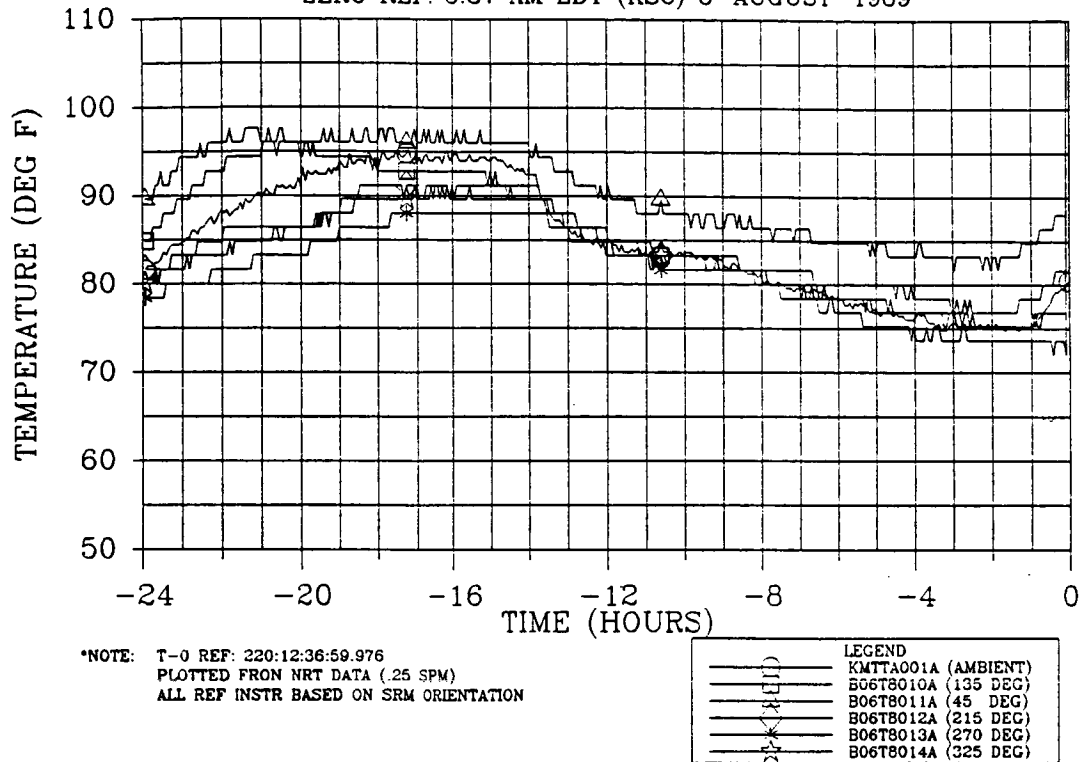


Figure 4.8-61. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreage Temperature at Station 931.5 Overlaid With Ambient

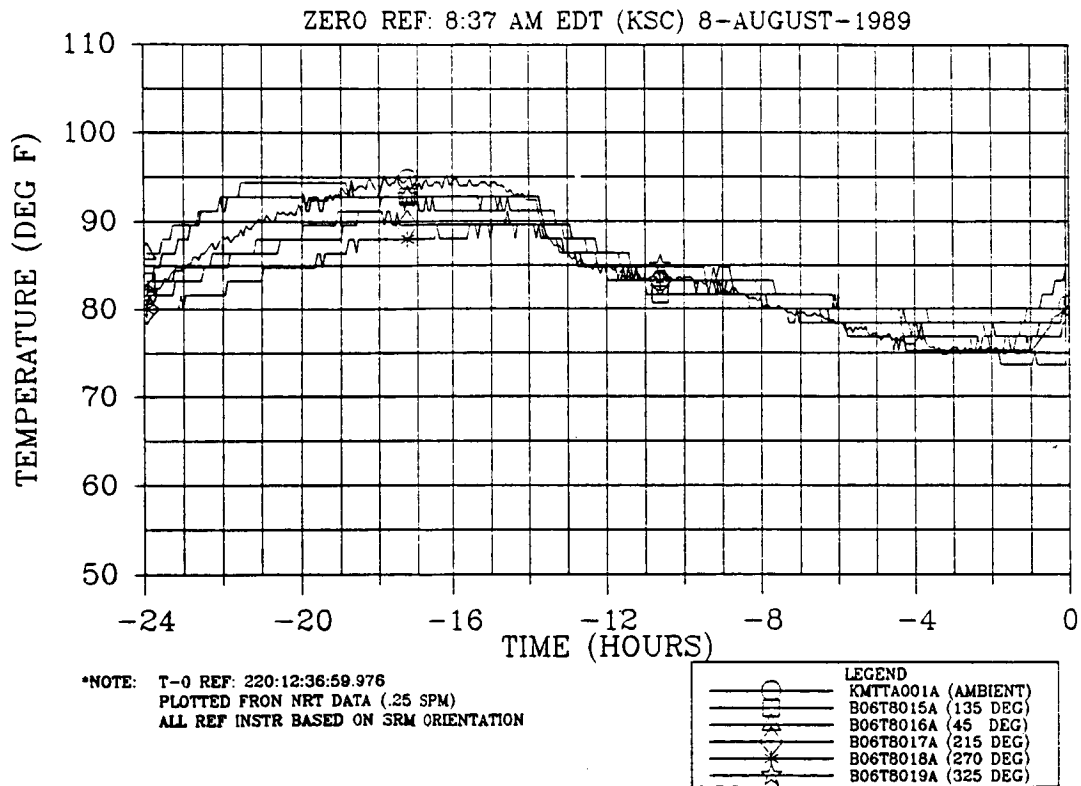


Figure 4.8-62. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreage Temperature at Station 1091.5 Overlaid With Ambient

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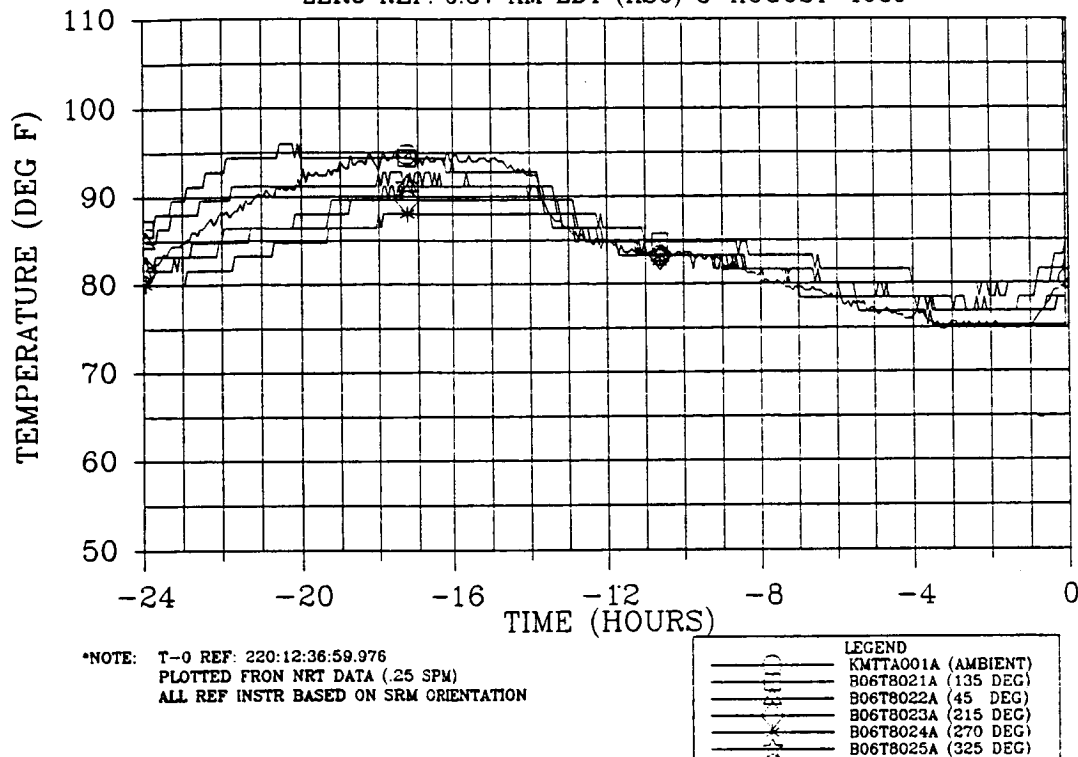


Figure 4.8-63. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreage Temperature at Station 1411.5 Overlaid With Ambient

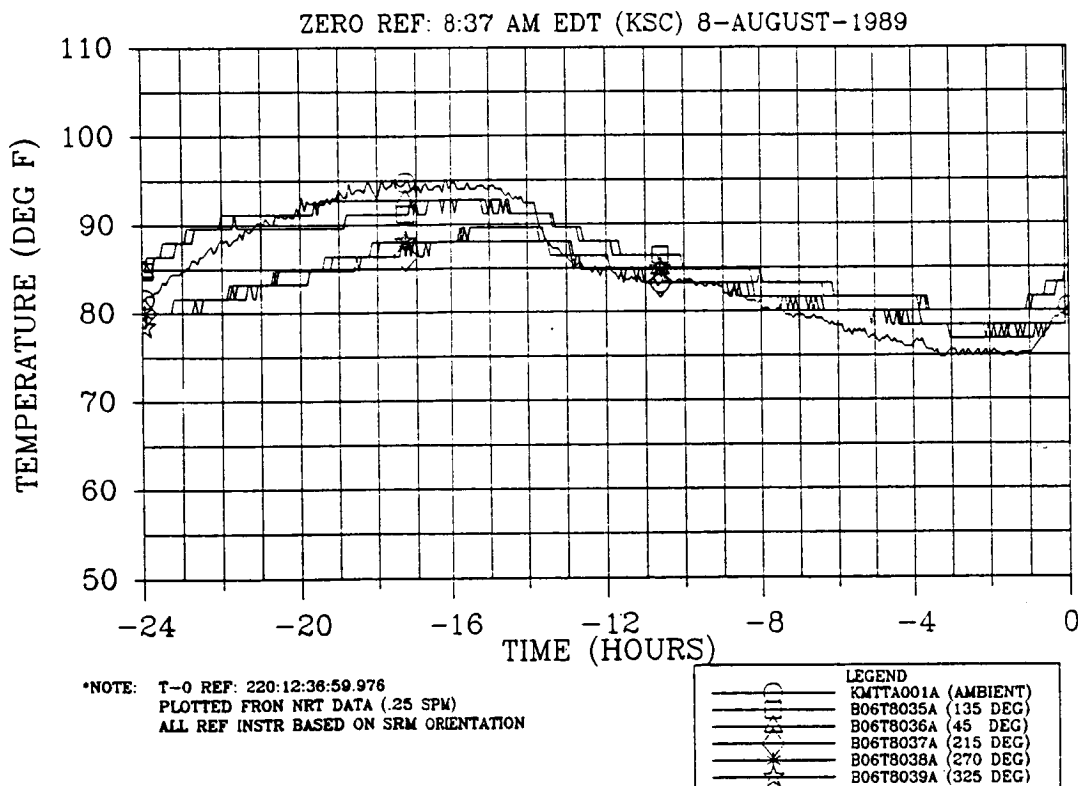


Figure 4.8-64. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreage Temperature at Station 1751.5 Overlaid With Ambient

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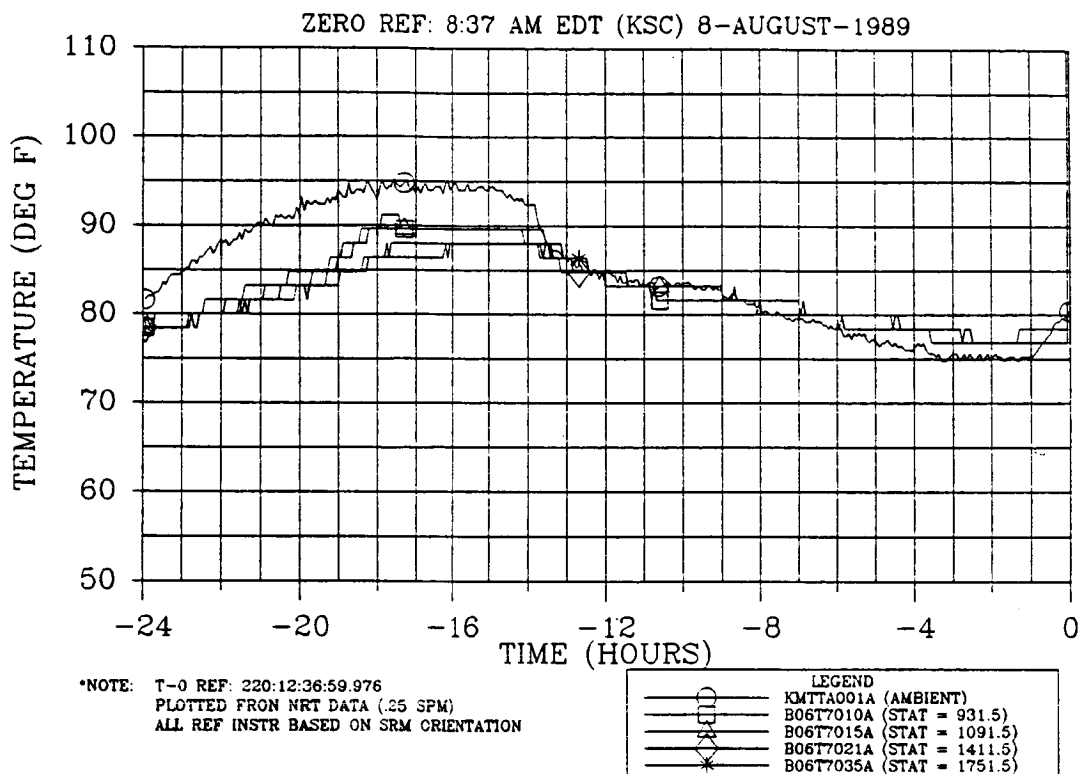


Figure 4.8-65. 360H005 (STS-28) Launch — 24-hr LH SRM Case Acreage Temperature at 45-deg Location Overlaid With Ambient

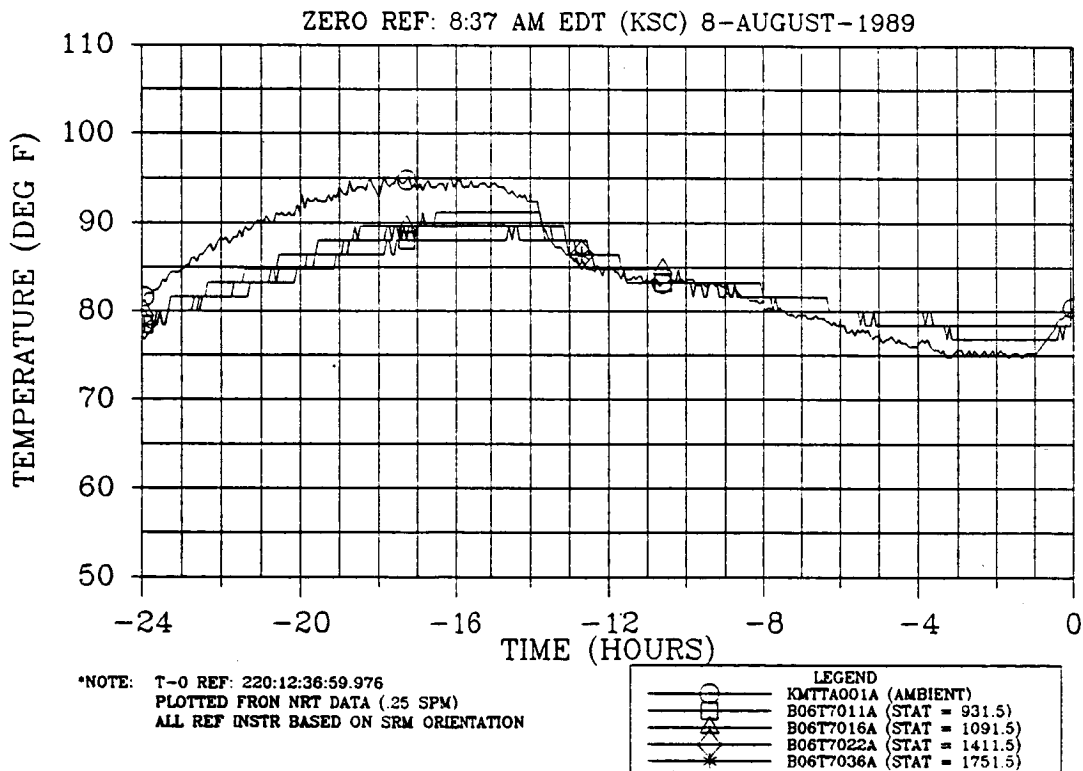


Figure 4.8-66. 360H005 (STS-28) Launch — 24-hr LH SRM Case Acreage Temperature at 135-deg Location Overlaid With Ambient

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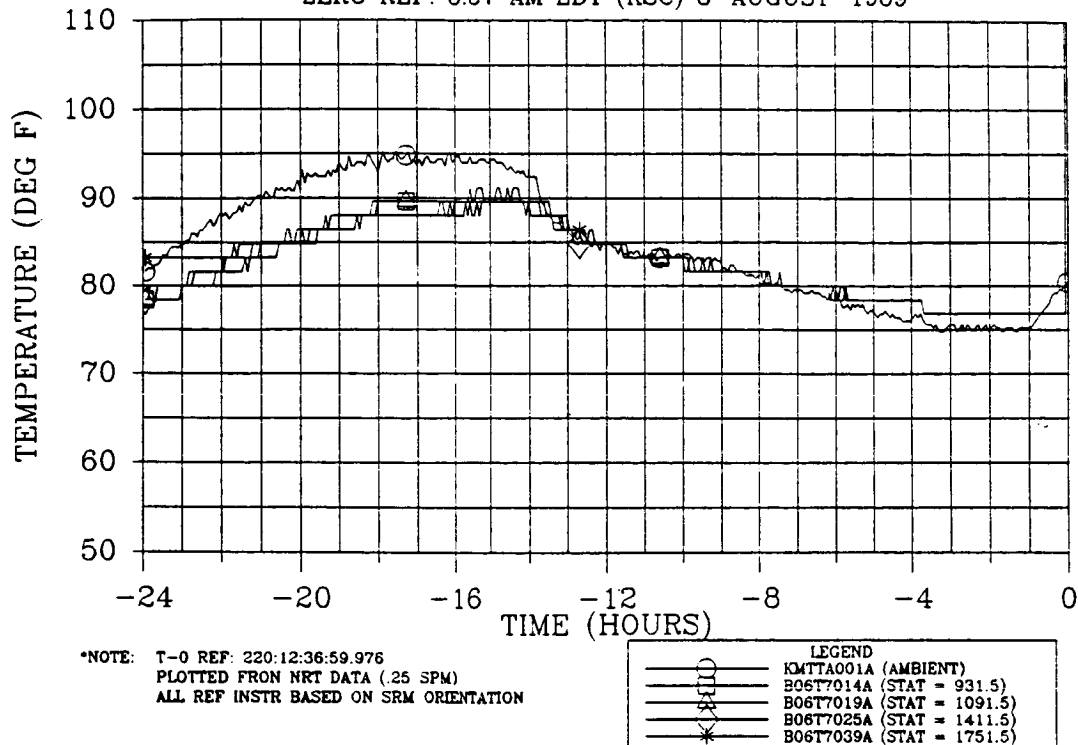


Figure 4.8-67. 360H005 (STS-28) Launch — 24-hr LH SRM Case Acreage Temperature at 215-deg Location Overlaid With Ambient

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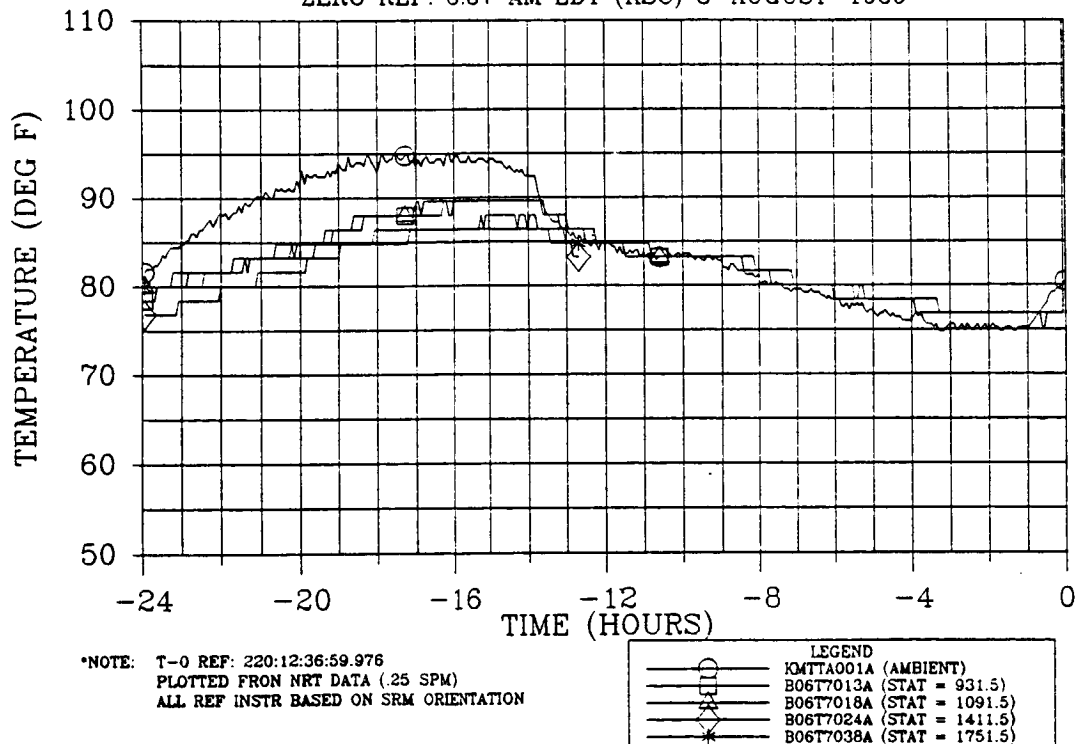


Figure 4.8-68. 360H005 (STS-28) Launch — 24-hr LH SRM Case Acreage Temperature at 270-deg Location Overlaid With Ambient

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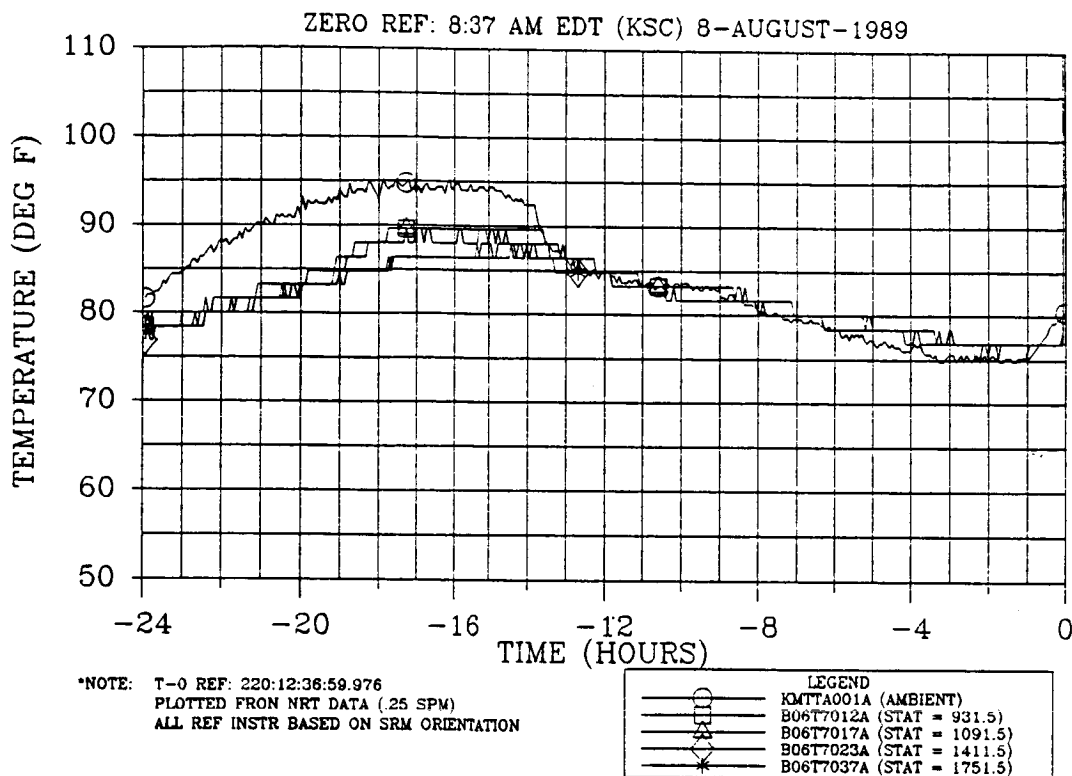


Figure 4.8-69. 360H005 (STS-28) Launch — 24-hr LH SRM Case Acreage Temperature at 325-deg Location Overlaid With Ambient

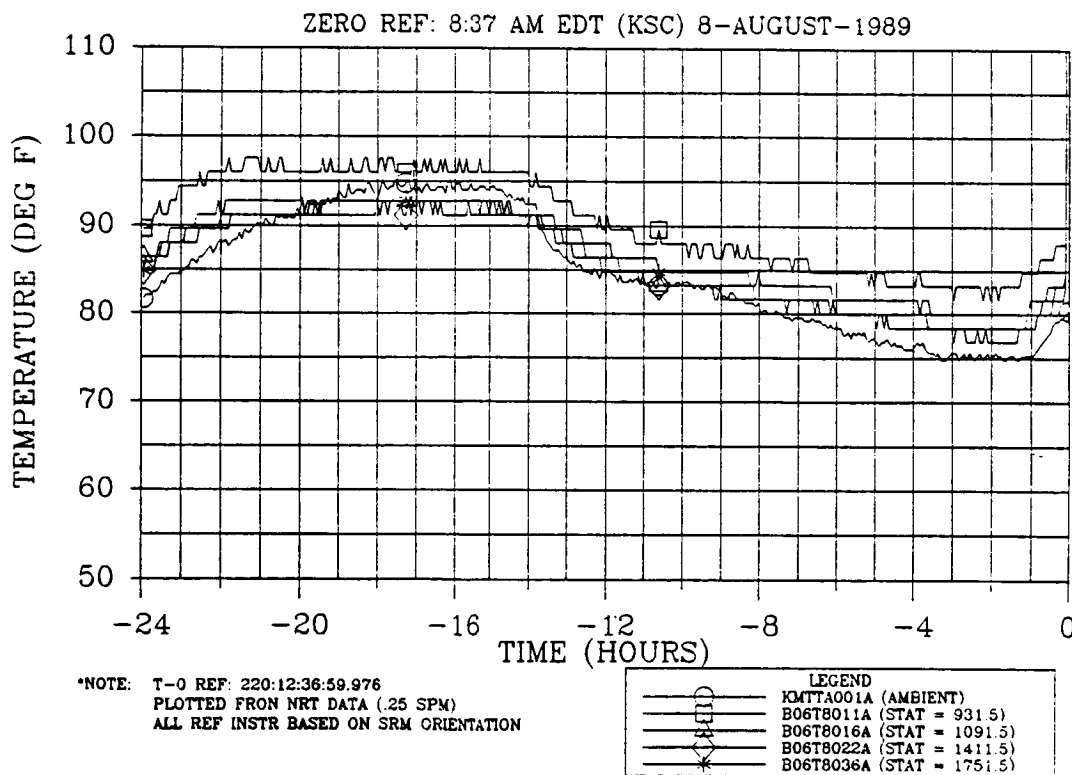


Figure 4.8-70. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreage Temperature at 45-deg Location Overlaid With Ambient

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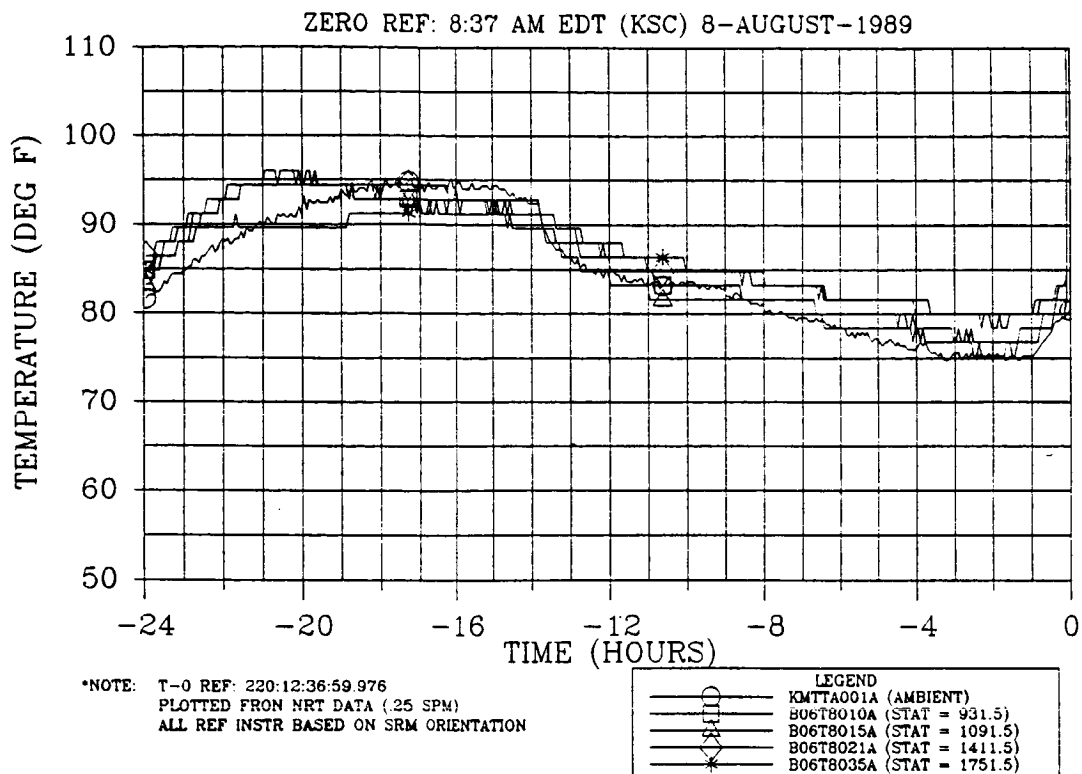


Figure 4.8-71. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreege Temperature at 135-deg Location Overlaid With Ambient

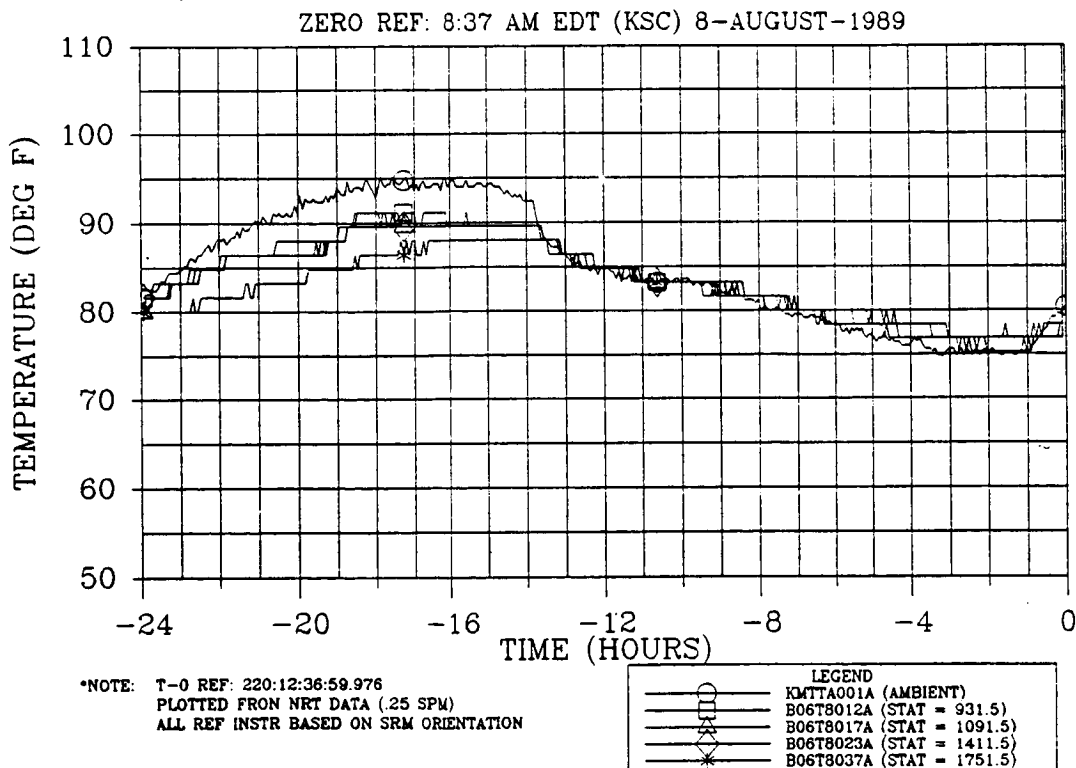


Figure 4.8-72. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreege Temperature at 215-deg Location Overlaid With Ambient

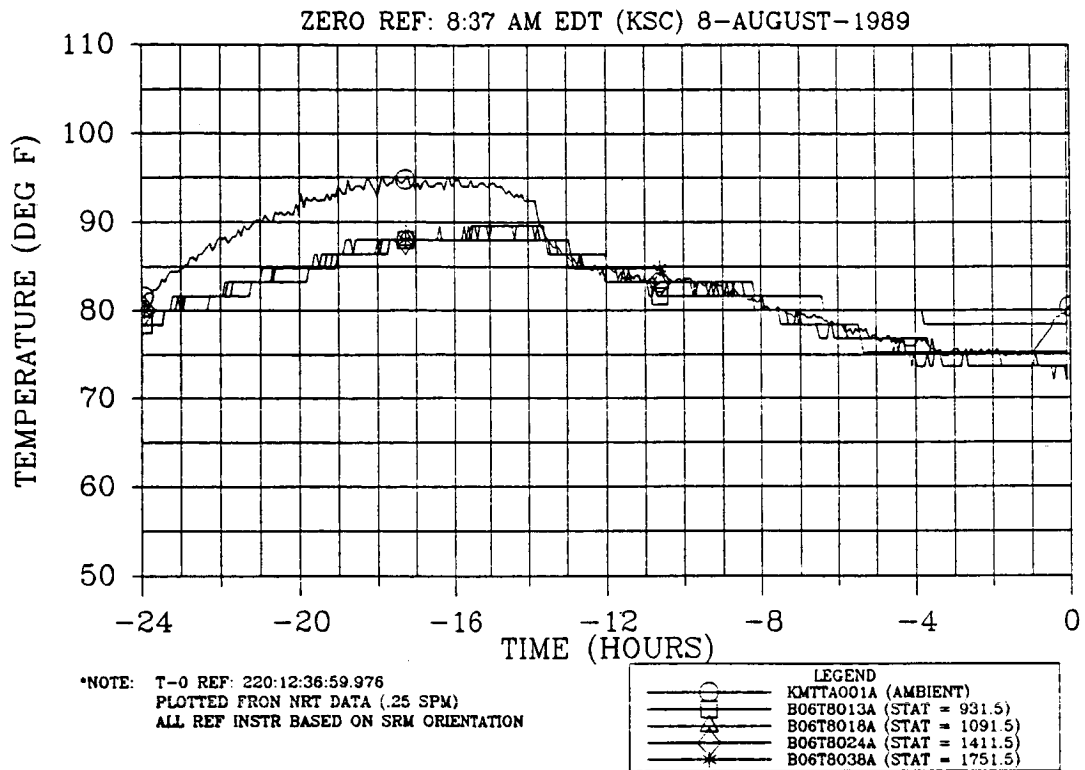


Figure 4.8-73. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreage Temperature at 270-deg Location Overlaid With Ambient

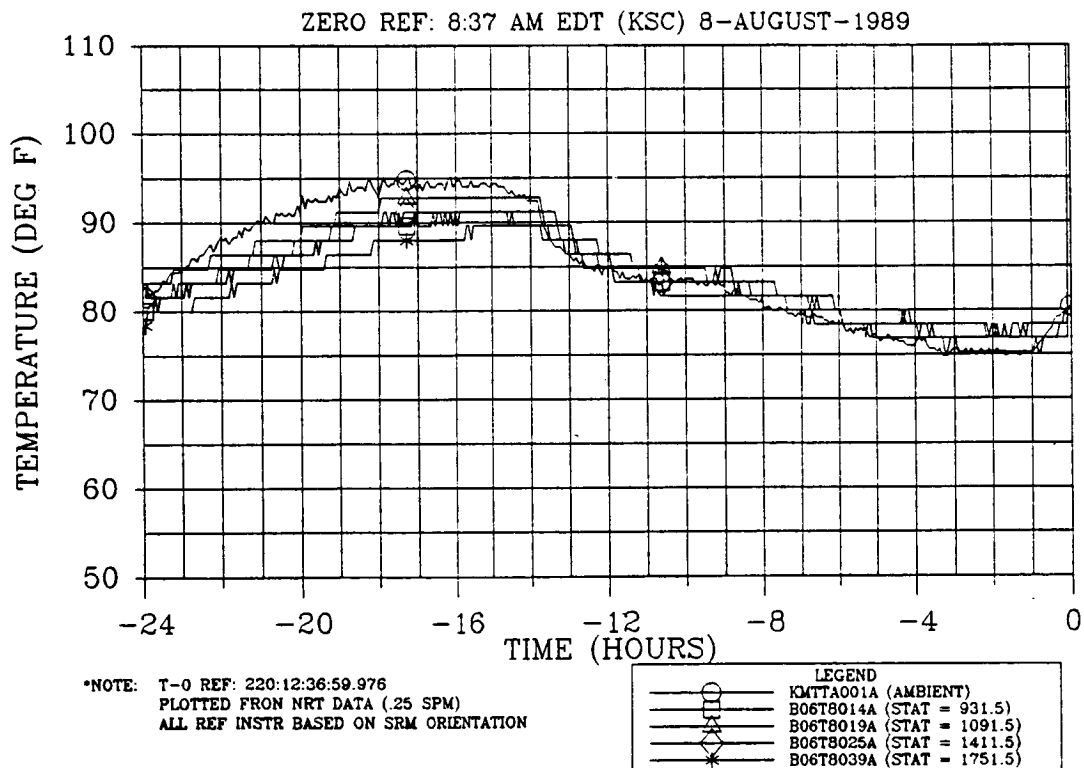


Figure 4.8-74. 360H005 (STS-28) Launch — 24-hr RH SRM Case Acreage Temperature at 325-deg Location Overlaid With Ambient

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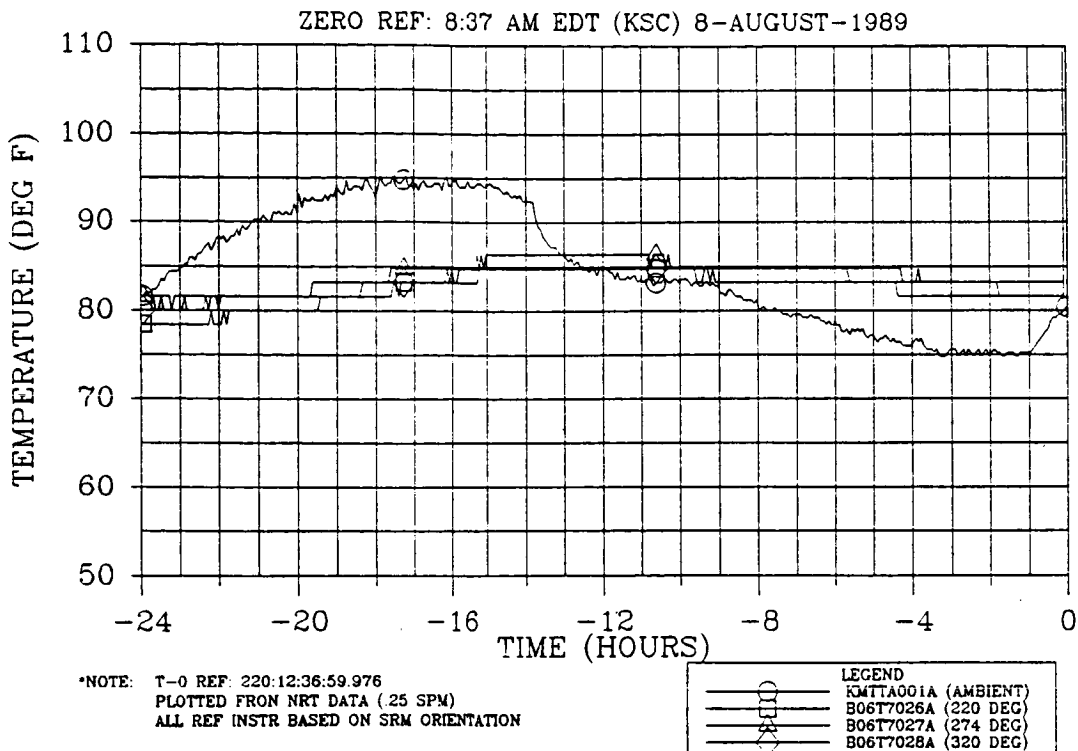


Figure 4.8-75. 360H005 (STS-28) Launch — 24-hr LH SRM ET Attach Region Temperature at Station 1511.0 Overlaid With Ambient

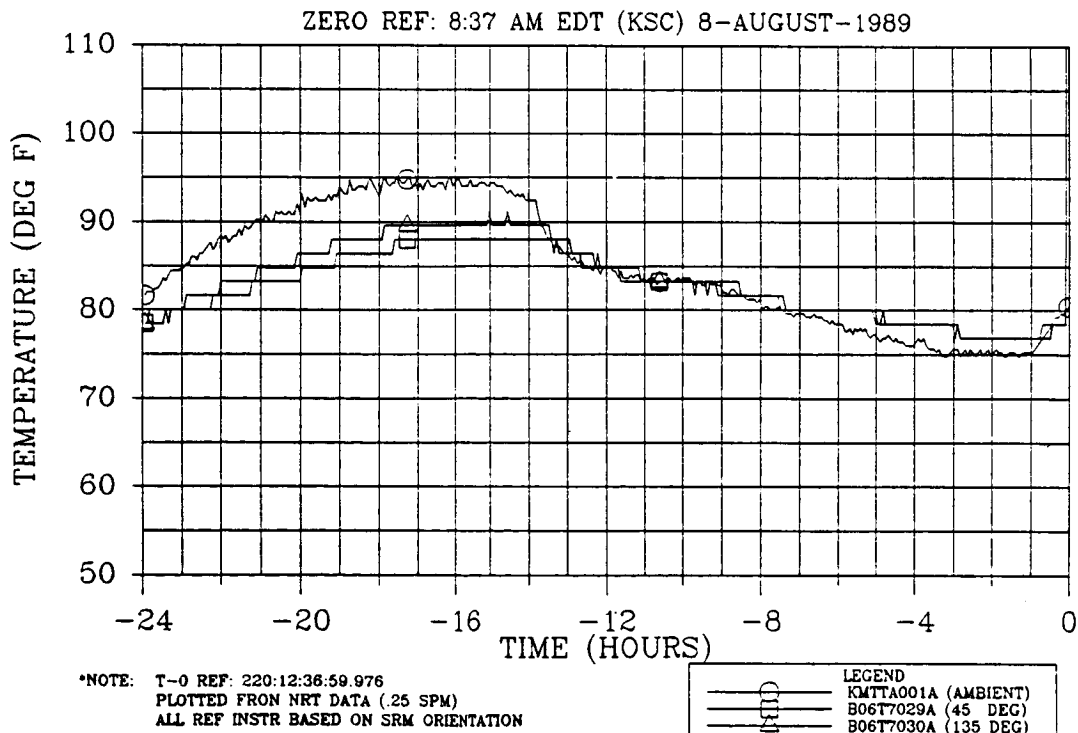


Figure 4.8-76. 360H005 (STS-28) Launch — 24-hr LH SRM ET Attach Region Temperature at Station 1535.0 Overlaid With Ambient

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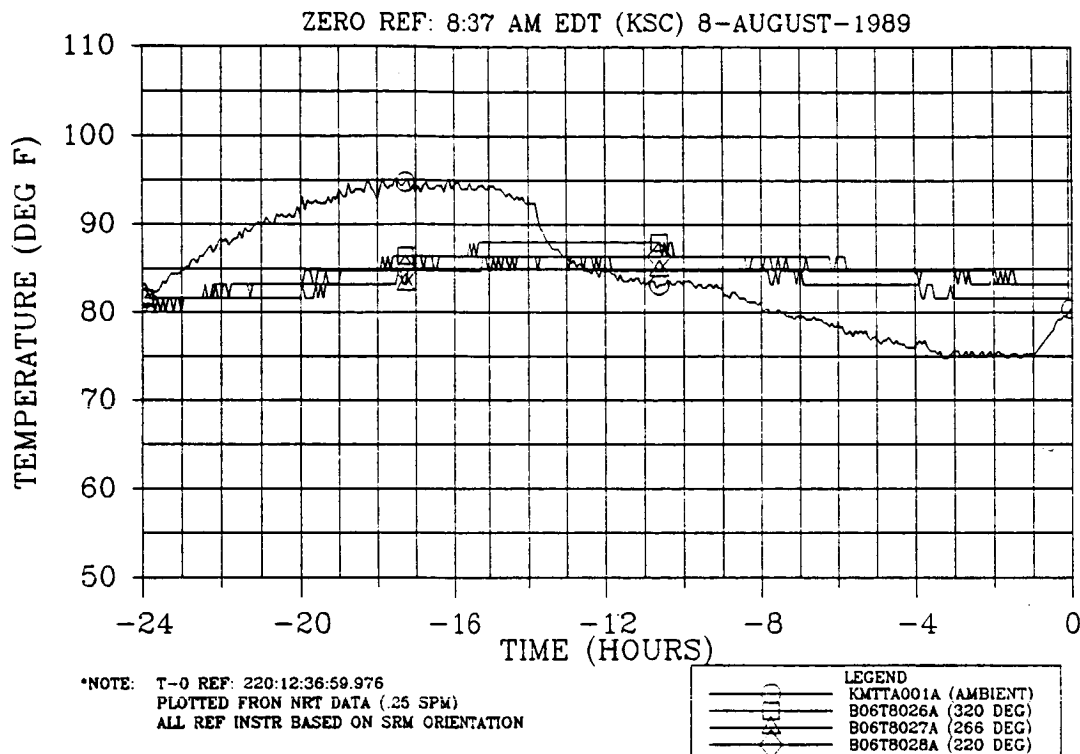


Figure 4.8-77. 360H005 (STS-28) Launch — 24-hr RH SRM ET Attach Region Temperature at Station 1511.0 Overlaid With Ambient

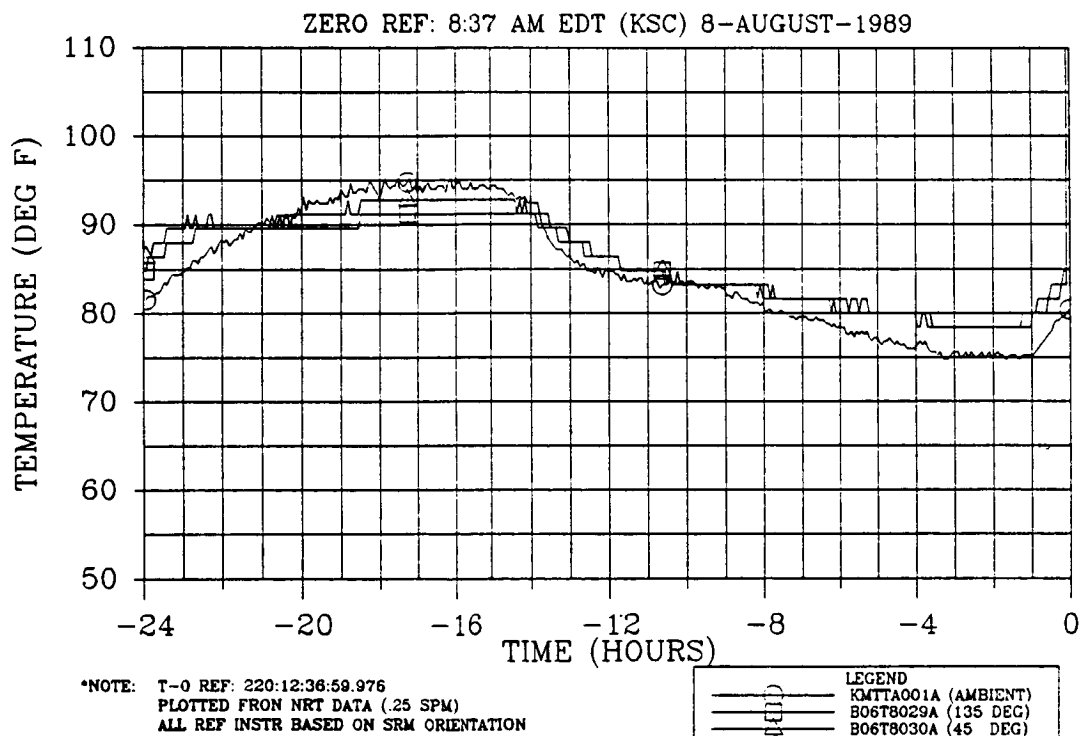


Figure 4.8-78. 360H005 (STS-28) Launch — 24-hr RH SRM ET Attach Region Temperature at Station 1535.0 Overlaid With Ambient

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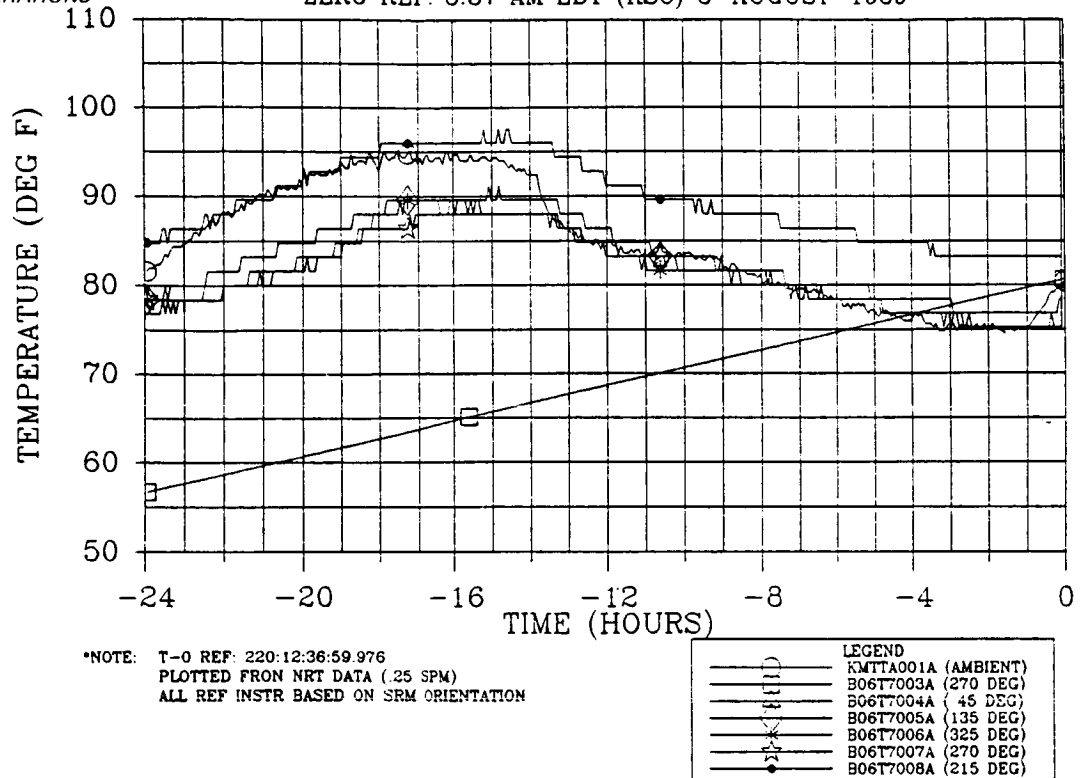


Figure 4.8-79. 360H005 (STS-28) Launch — 24-hr LH SRM Forward Factory Joint Temperature Overlaid With Ambient

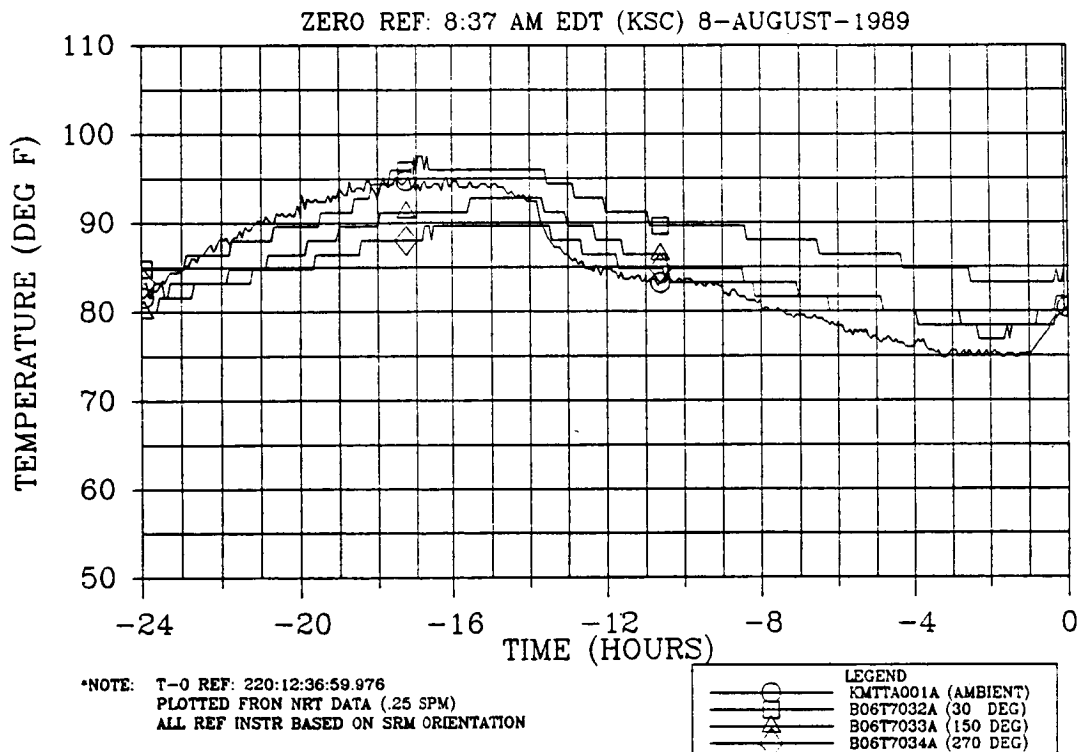


Figure 4.8-80. 360H005 (STS-28) Launch — 24-hr LH SRM Aft Factory Joint Temperature at Station 1701.9 Overlaid With Ambient

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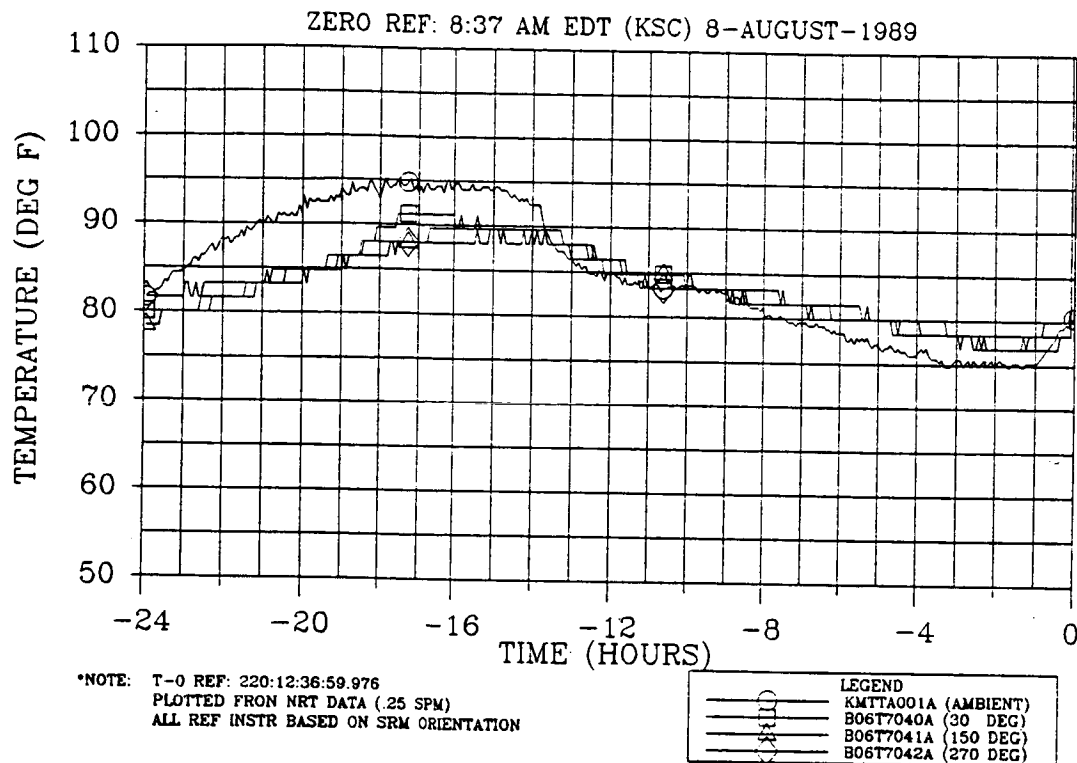


Figure 4.8-81. 360H005 (STS-28) Launch — 24-hr LH SRM Aft Factory Joint Temperature at Station 1821.0 Overlaid With Ambient
ZERO REF: 8:37 AM EDT (KSC) 8-AUGUST-1989

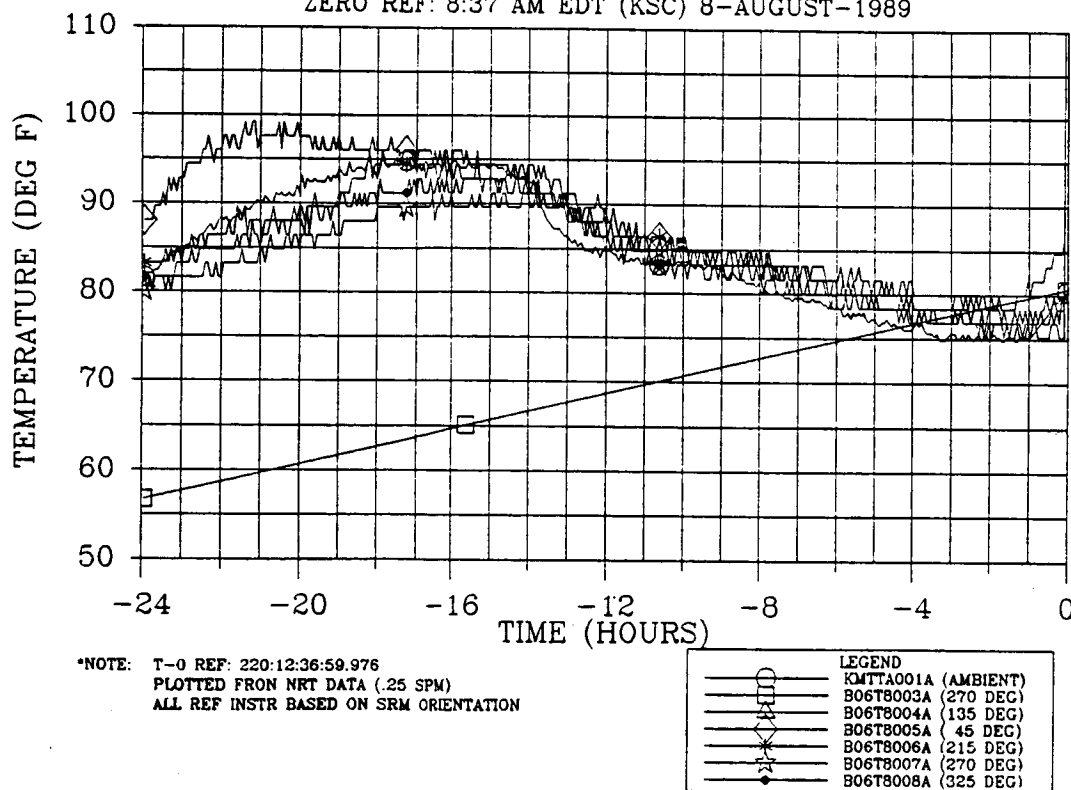


Figure 4.8-82. 360H005 (STS-28) Launch — 24-hr RH SRM Forward Factory Joint Temperature Overlaid With Ambient

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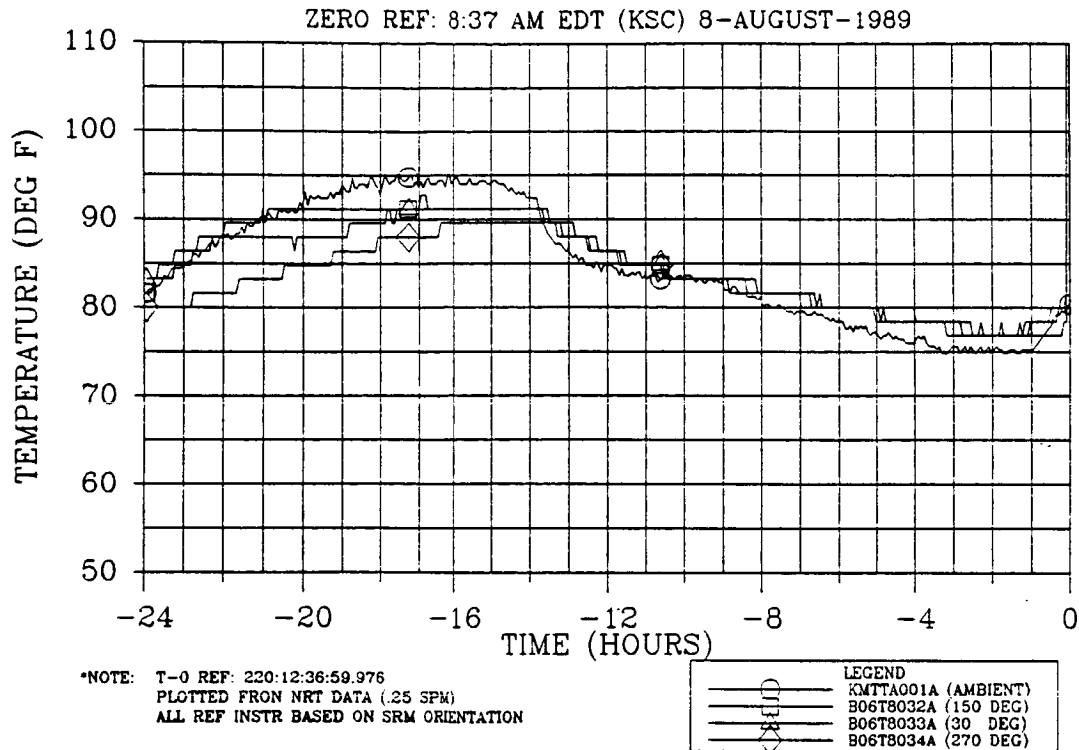


Figure 4.8-83. 360H005 (STS-28) Launch — 24-hr RH SRM Aft Factory Joint Temperature at Station 1701.9 Overlaid With Ambient

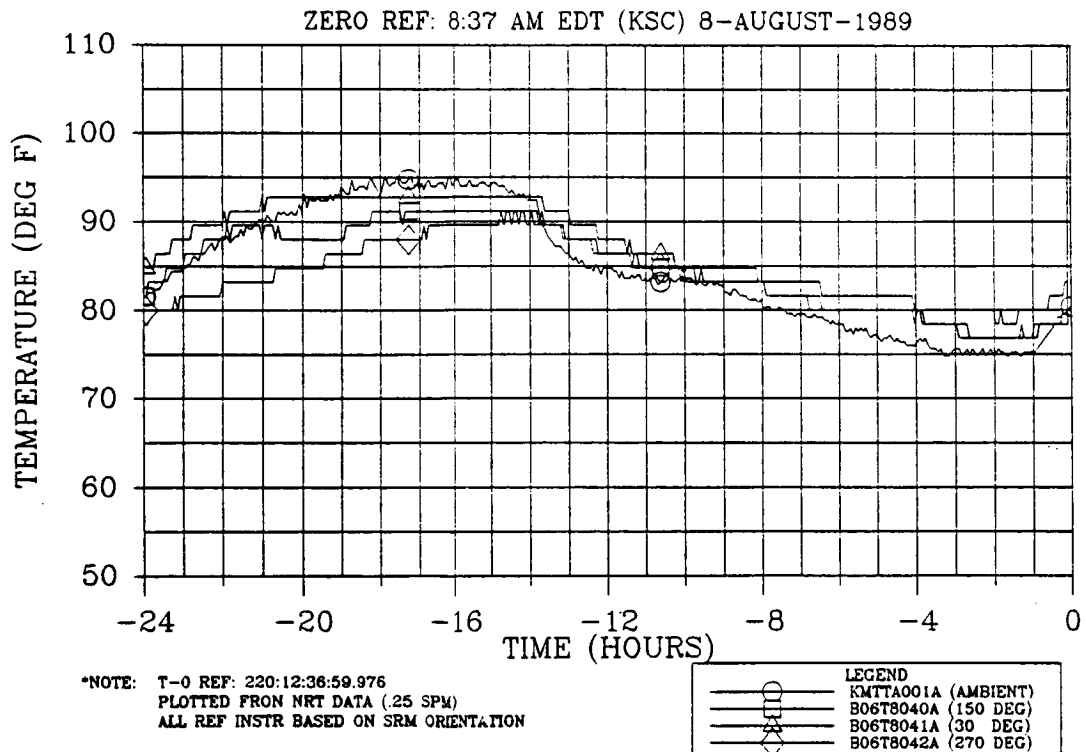


Figure 4.8-84. 360H005 (STS-28) Launch — 24-hr RH SRM Aft Factory Joint Temperature at Station 1821.0 Overlaid With Ambient

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ZERO REF: 8:37 AM EDT (KSC) 8-AUGUST-1989

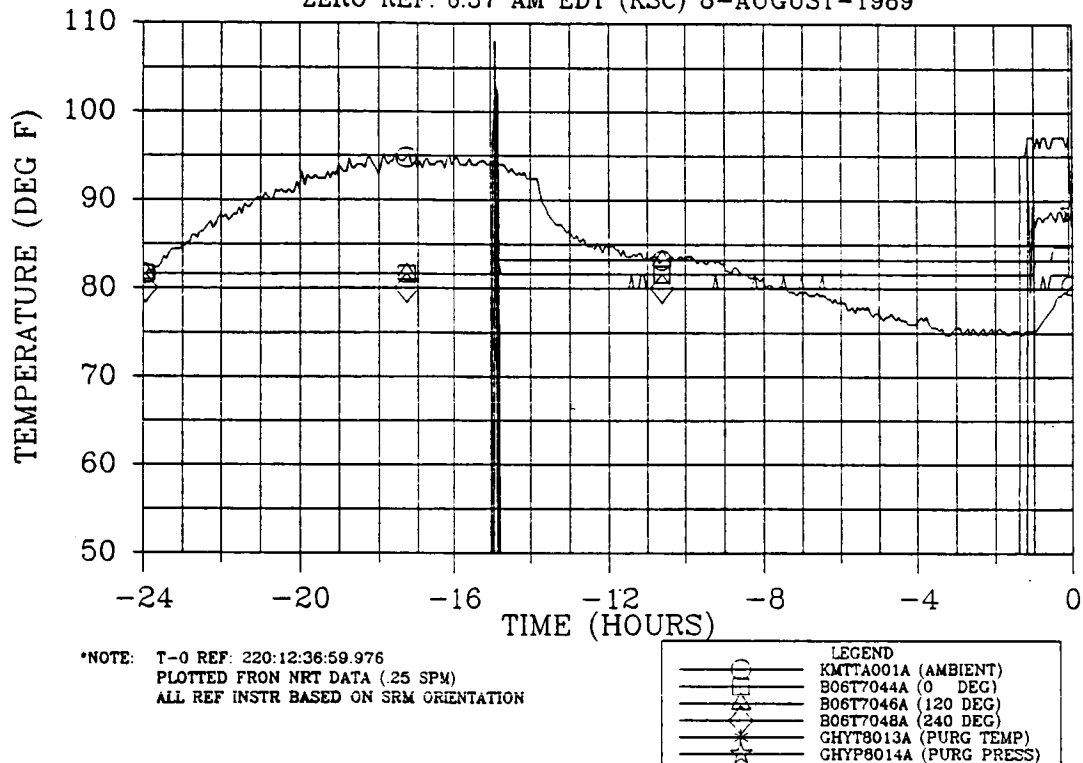


Figure 4.8-85. 360H005 (STS-28) Launch — 24-hr LH SRM Nozzle Region Temperature at Station 1845.0 Overlaid With Ambient

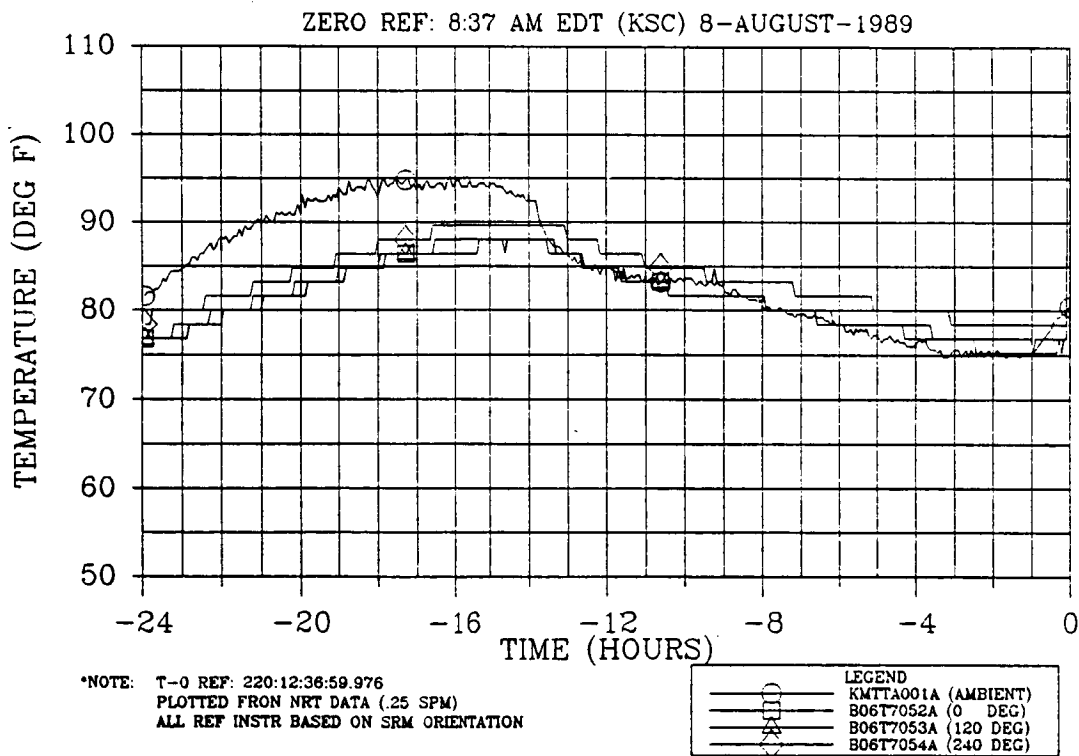


Figure 4.8-86. 360H005 (STS-28) Launch — 24-hr LH SRM Nozzle Region Temperature at Station 1950.0 Overlaid With Ambient

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ZERO REF: 8:37 AM EDT (KSC) 8-AUGUST-1989

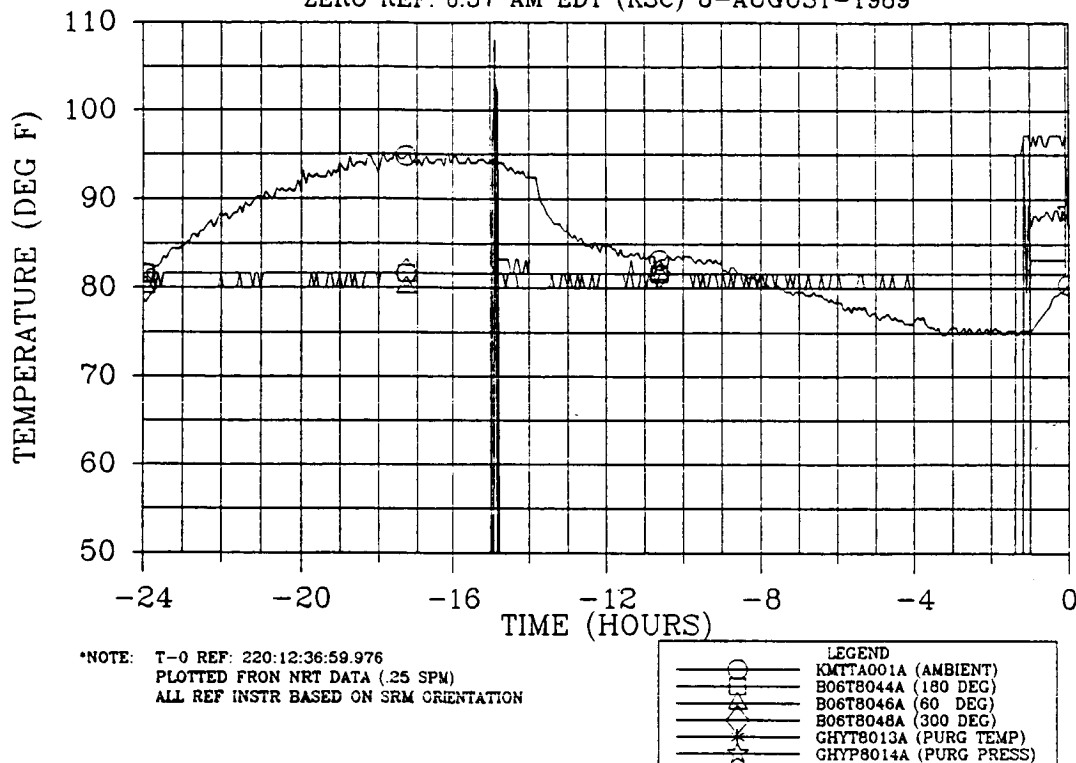


Figure 4.8-87. 360H005 (STS-28) Launch — 24-hr RH SRM Nozzle Region Temperature at Station 1845.0 Overlaid With Ambient

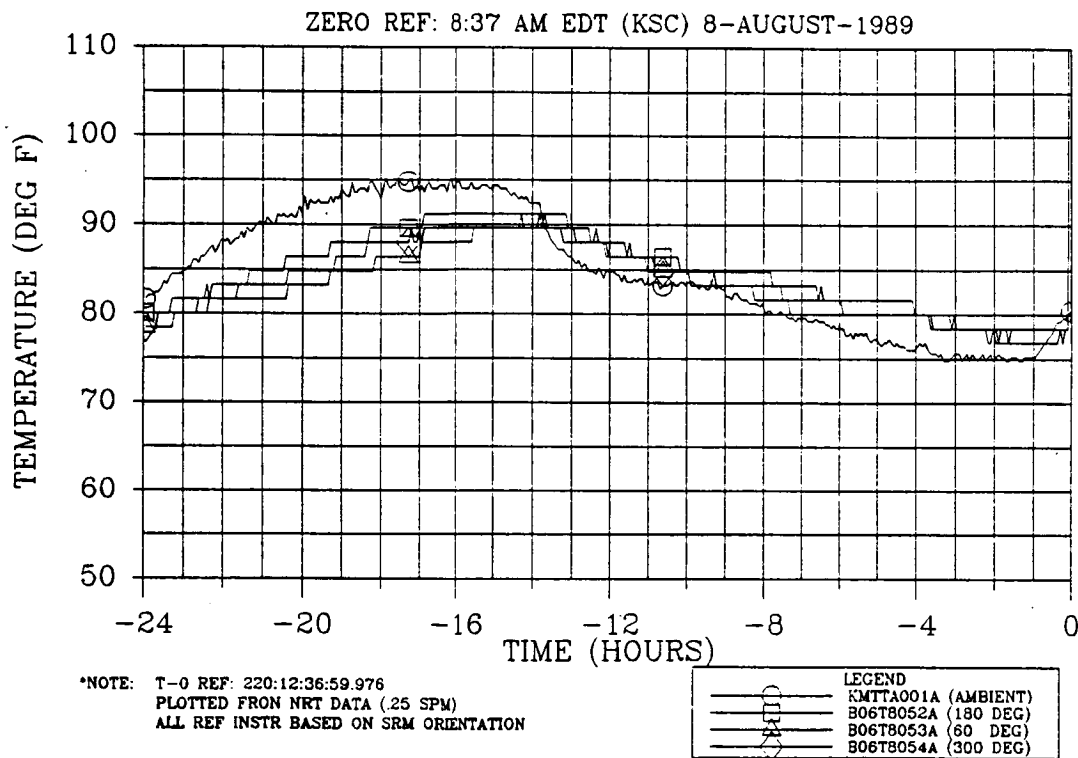


Figure 4.8-88. 360H005 (STS-28) Launch — 24-hr RH SRM Nozzle Region Temperature at Station 1950.0 Overlaid With Ambient

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ZERO REF: 8:37 AM EDT (KSC) 8-AUGUST-1989

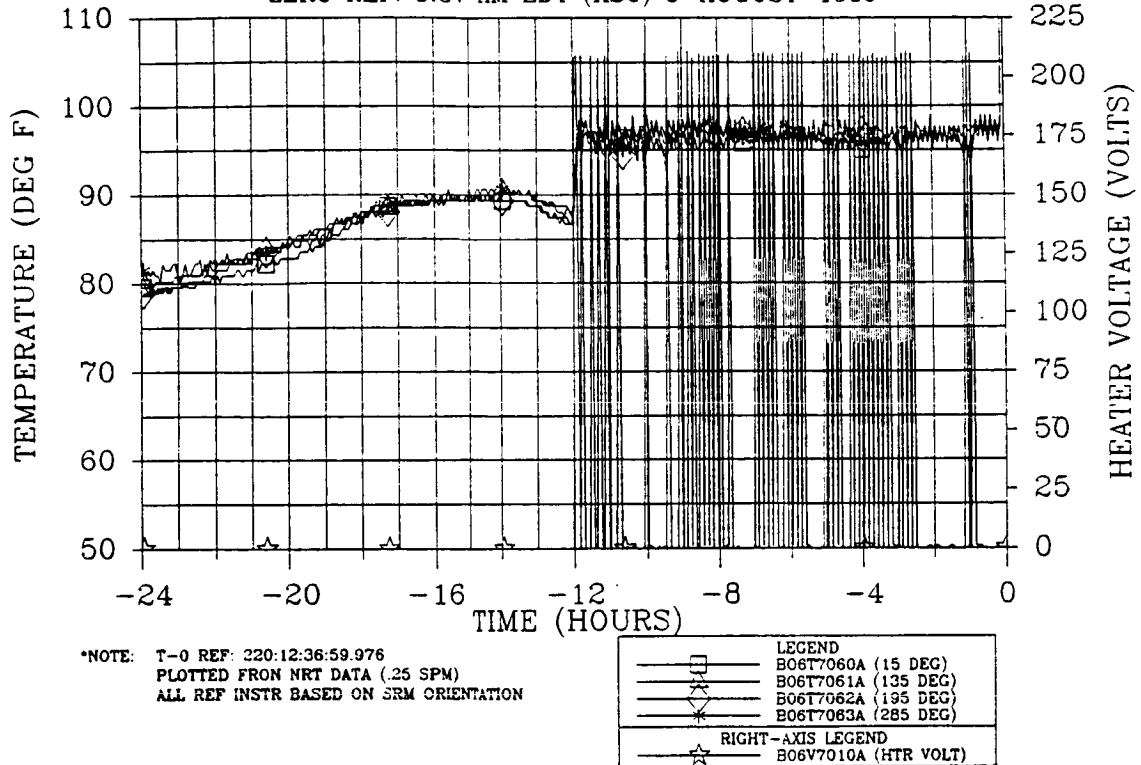


Figure 4.8-89. 360H005 (STS-28) Launch — 24-hr LH SRM Forward Field Joint Temperature Overlaid With Heater Voltage

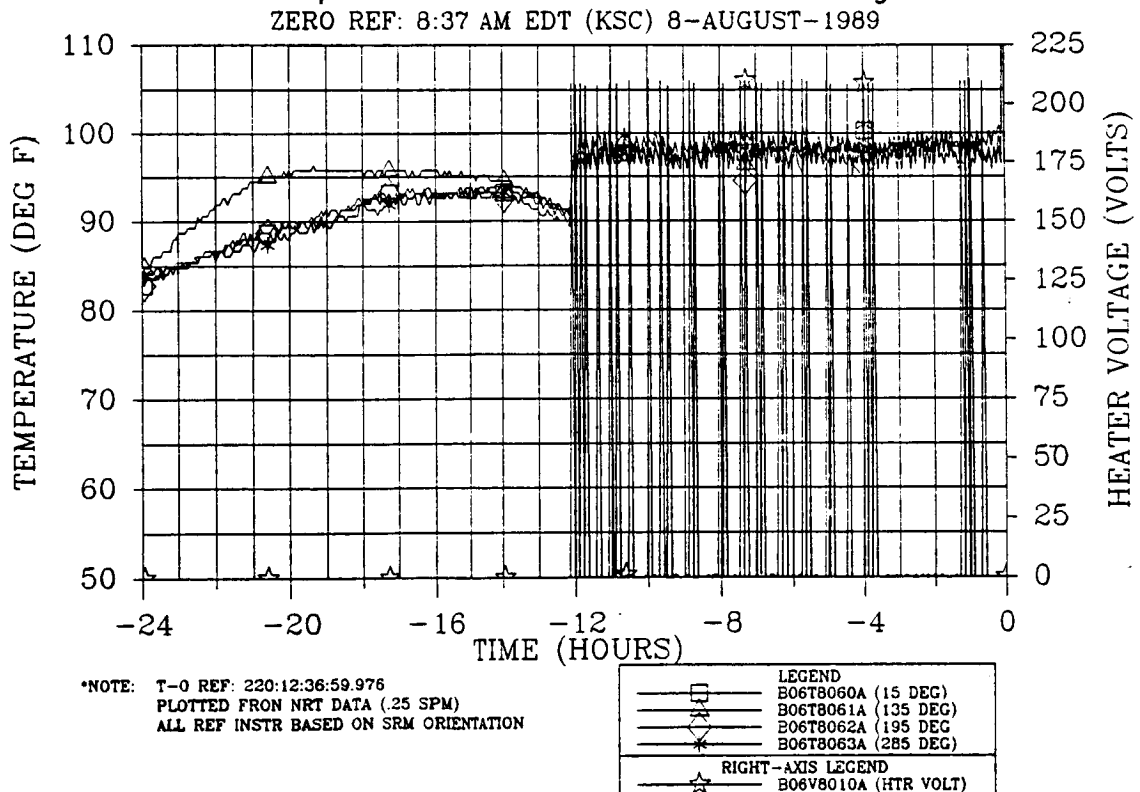


Figure 4.8-90. 360H005 (STS-28) Launch — 24-hr RH SRM Forward Field Joint Temperature Overlaid With Heater Voltage

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ZERO REF: 8:37 AM EDT (KSC) 8-AUGUST-1989

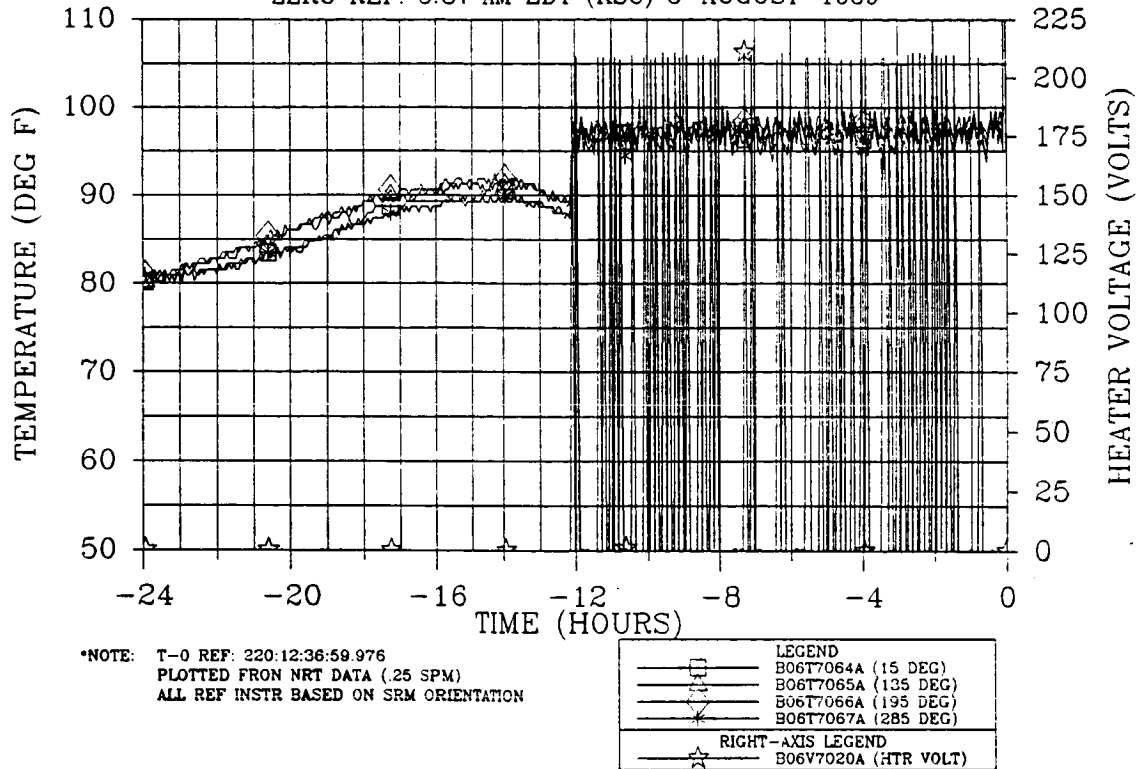


Figure 4.8-91. 360H005 (STS-28) Launch — 24-hr LH SRM Center Field Joint Temperature Overlaid With Heater Voltage

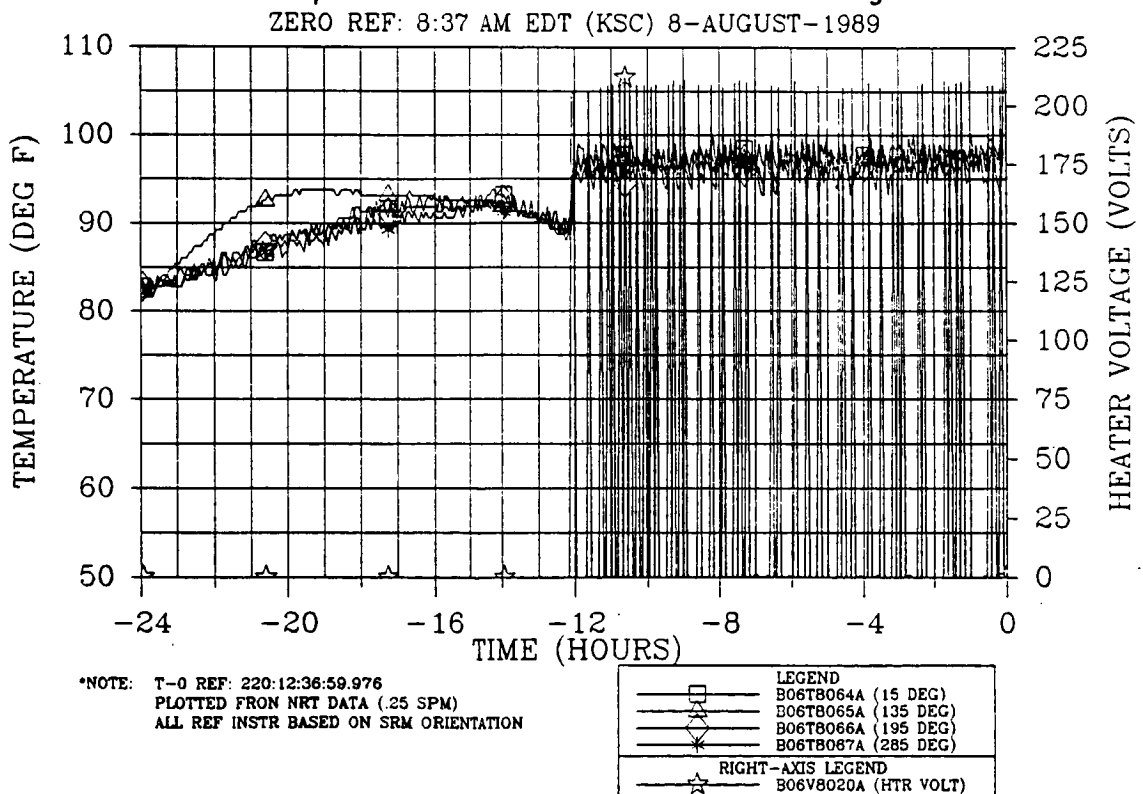


Figure 4.8-92. 360H005 (STS-28) Launch — 24-hr RH SRM Center Field Joint Temperature Overlaid With Heater Voltage

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ZERO REF: 8:37 AM EDT (KSC) 8-AUGUST-1989

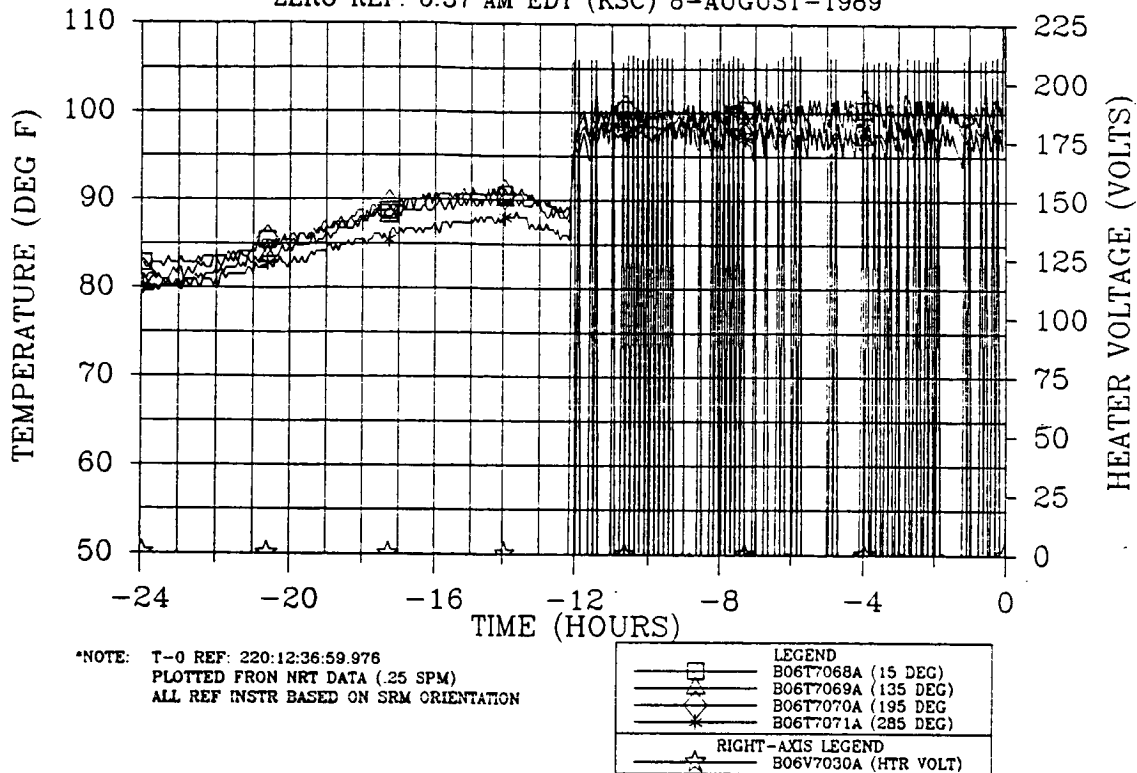


Figure 4.8-93. 360H005 (STS-28) Launch — 24-hr LH SRM Aft Field Joint Temperature Overlaid With Heater Voltage

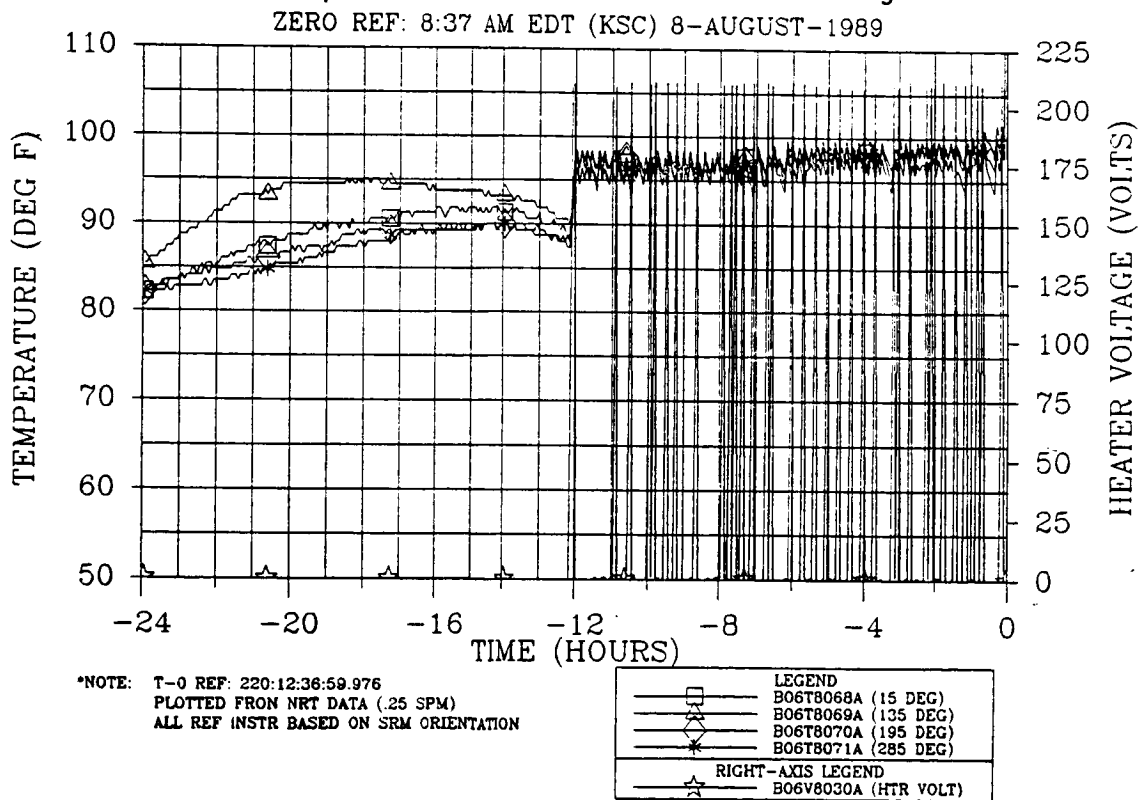


Figure 4.8-94. 360H005 (STS-28) Launch — 24-hr RH SRM Aft Field Joint Temperature Overlaid With Heater Voltage

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SEC | PAGE

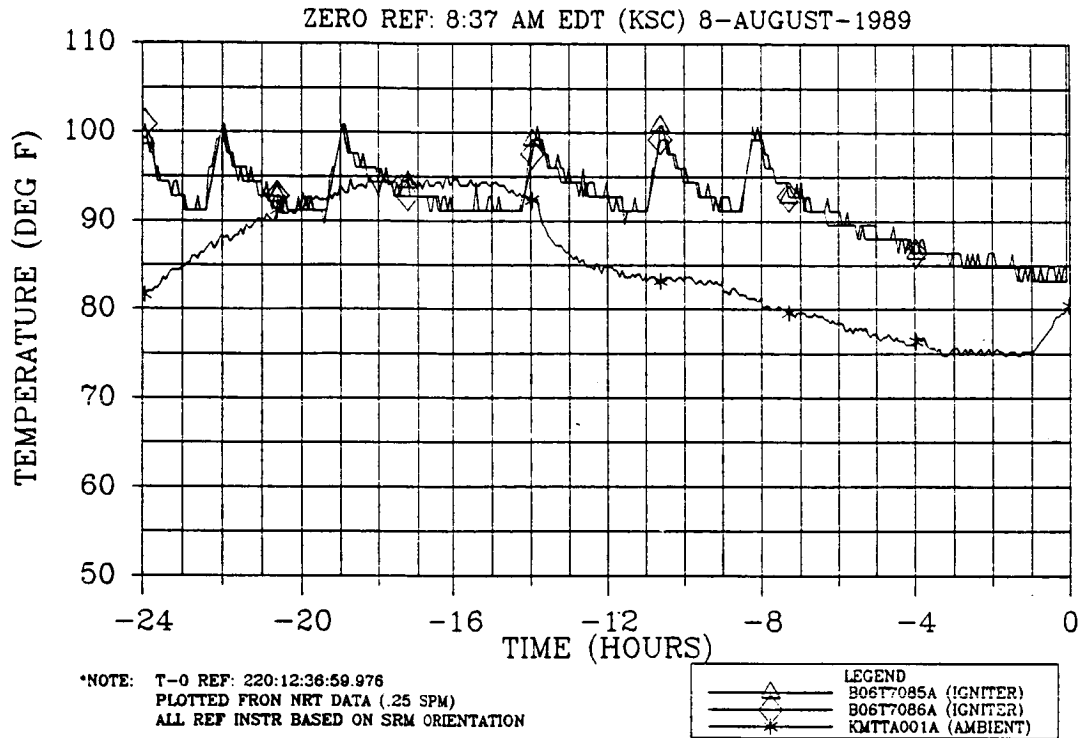


Figure 4.8-95. 360H005 (STS-28) Launch — 24-hr LH SRM Igniter Joint Temperatures Overlaid With Ambient

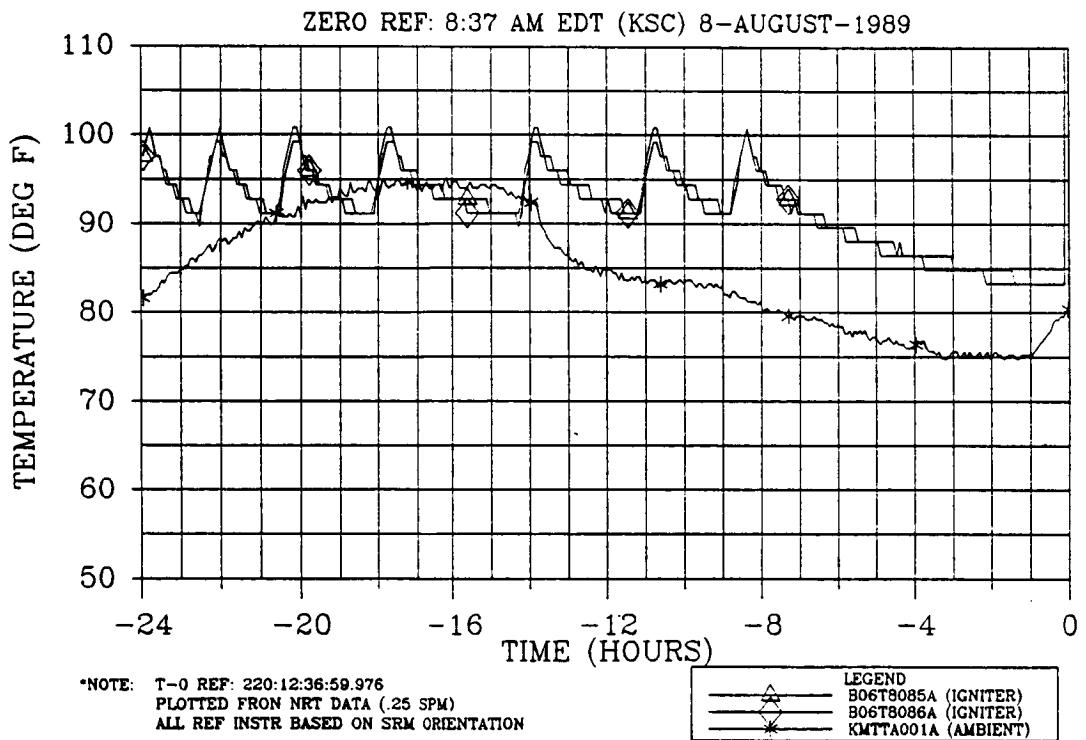


Figure 4.8-96. 360H005 (STS-28) Launch — 24-hr RH SRM Igniter Joint Temperatures Overlaid With Ambient

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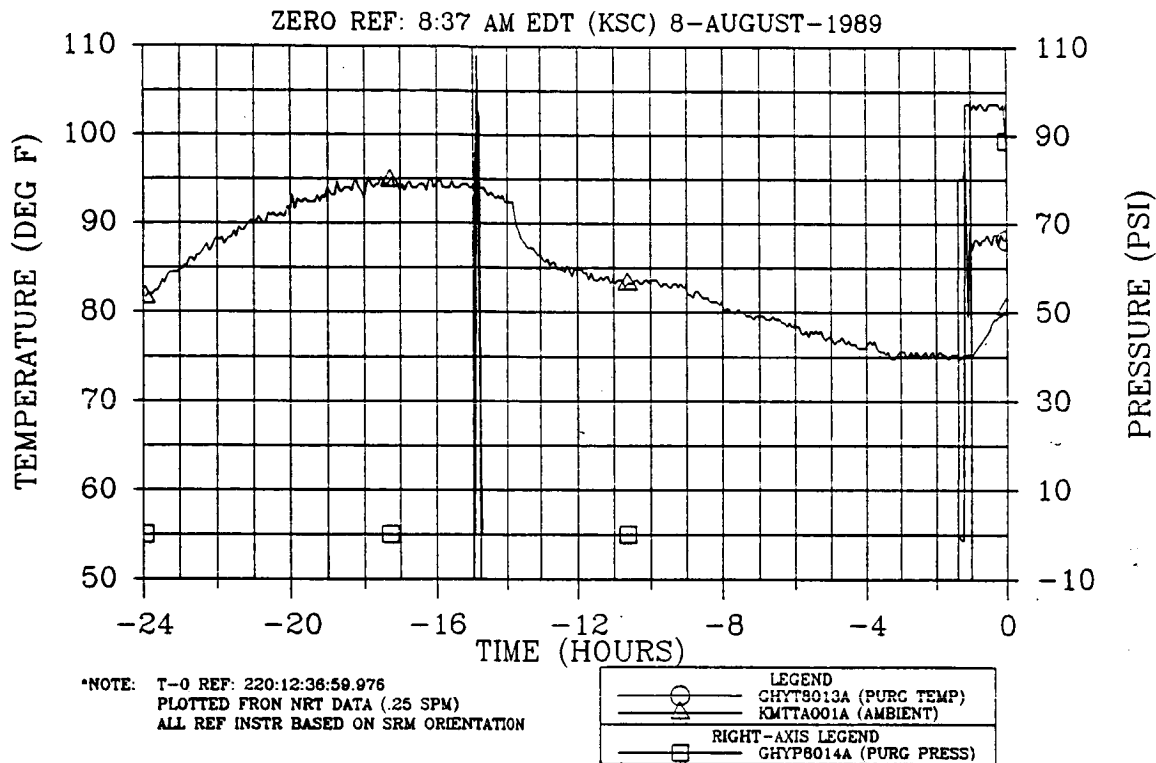


Figure 4.8-97. 360H005 (STS-28) Launch — 24-hr Aft Skirt Purge Temperature and Pressure Overlaid With Ambient

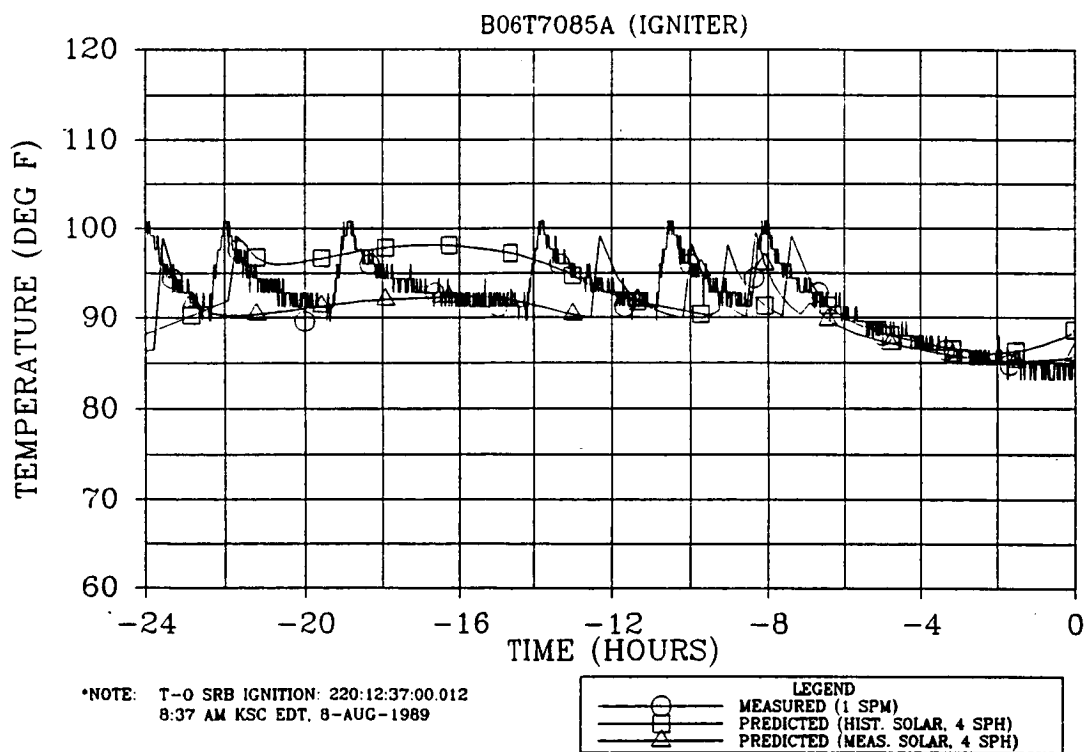


Figure 4.8-98. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for LH SRM Igniter Joint Temperatures

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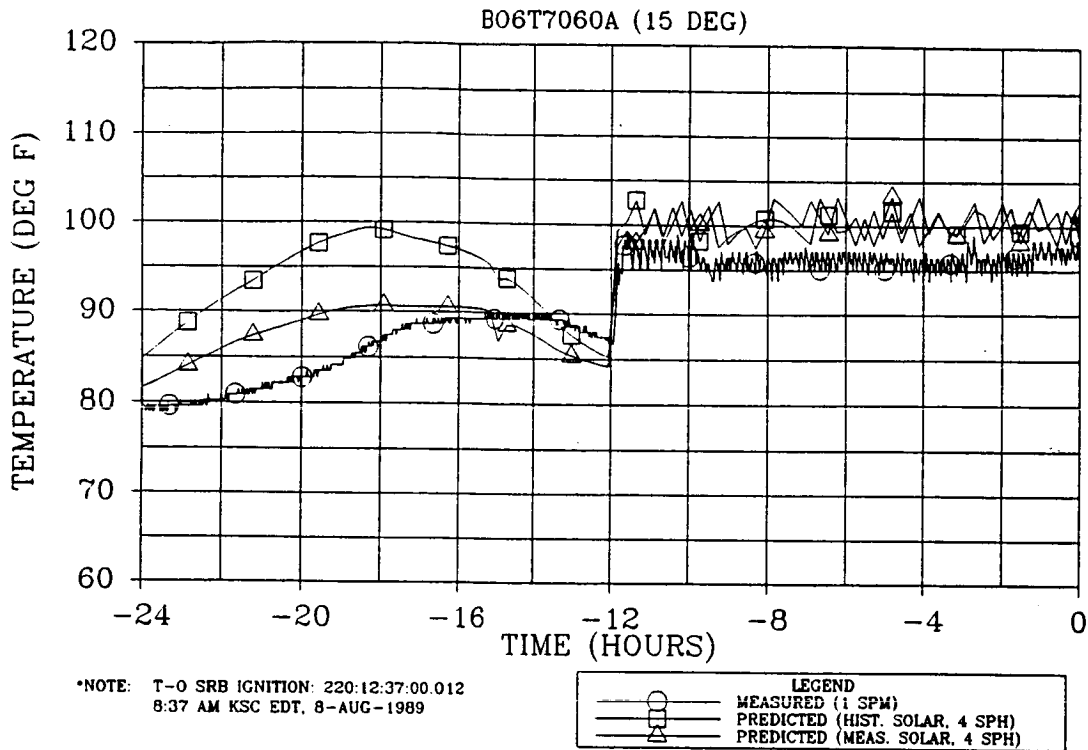


Figure 4.8-99. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for LH SRM Forward Field Joint Temperature

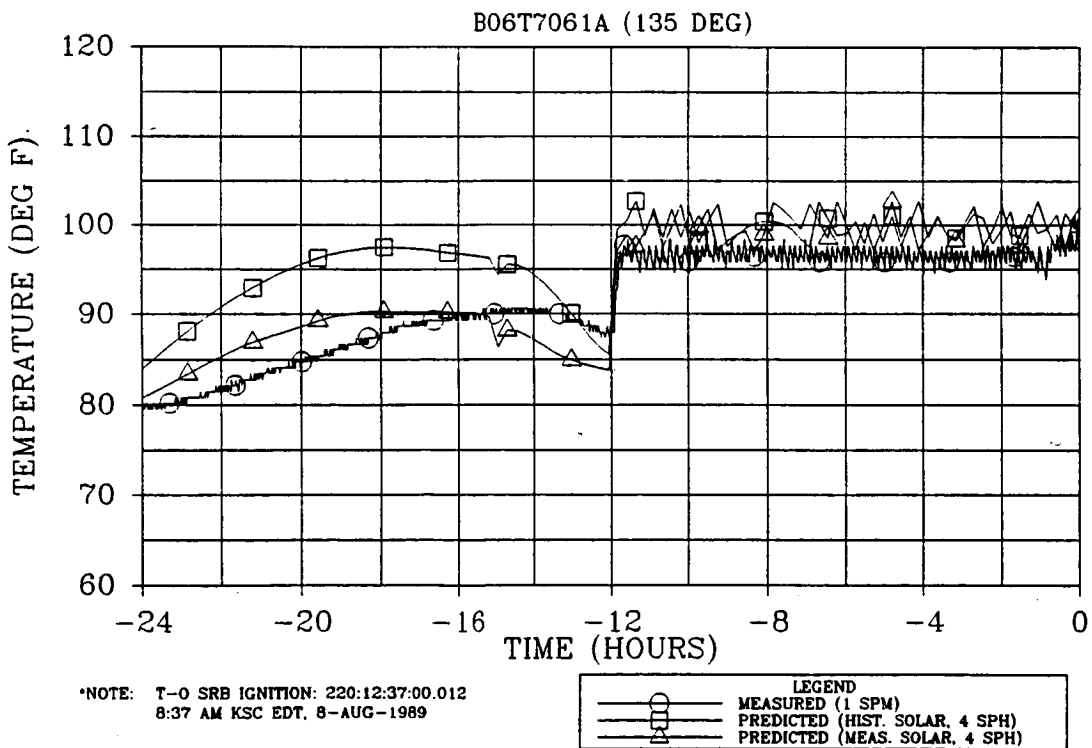


Figure 4.8-100. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for LH SRM Forward Field Joint Temperature

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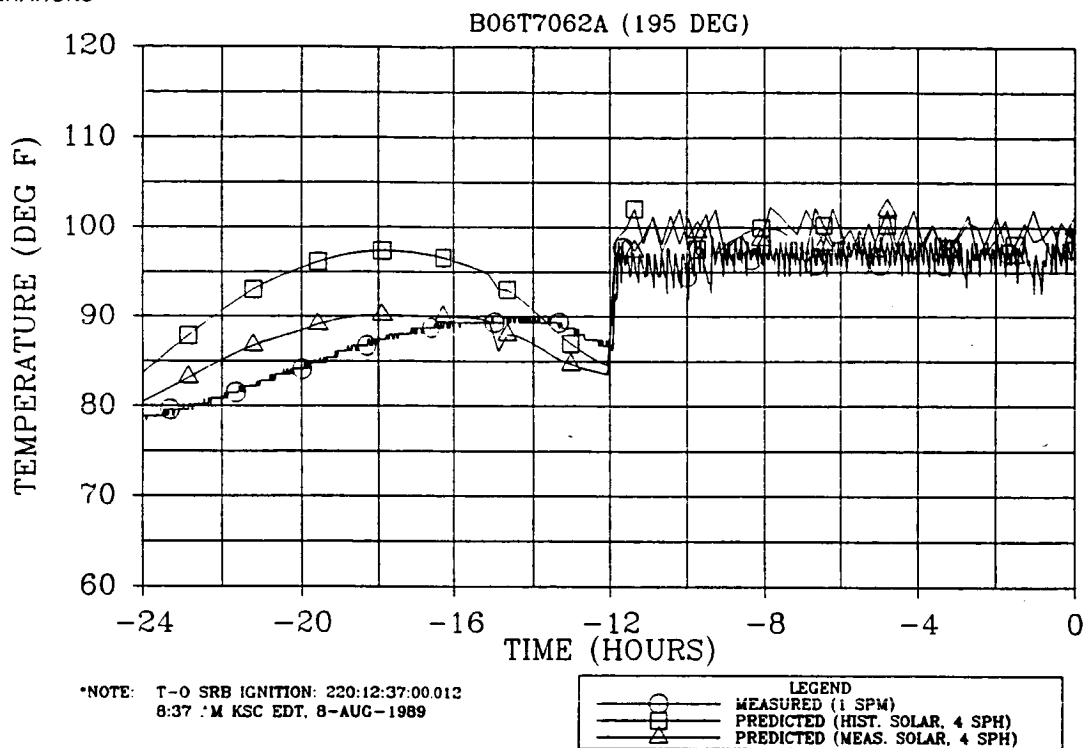


Figure 4.8-101. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for LH SRM Forward Field Joint Temperature

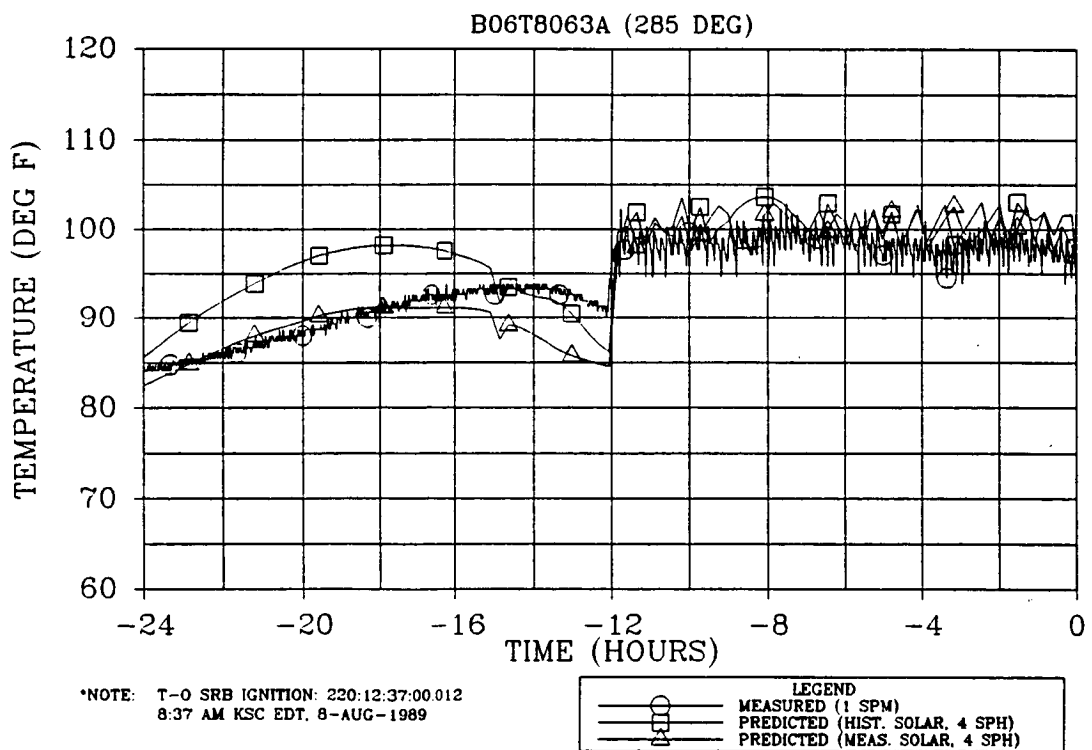


Figure 4.8-102. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Forward Field Joint Temperature

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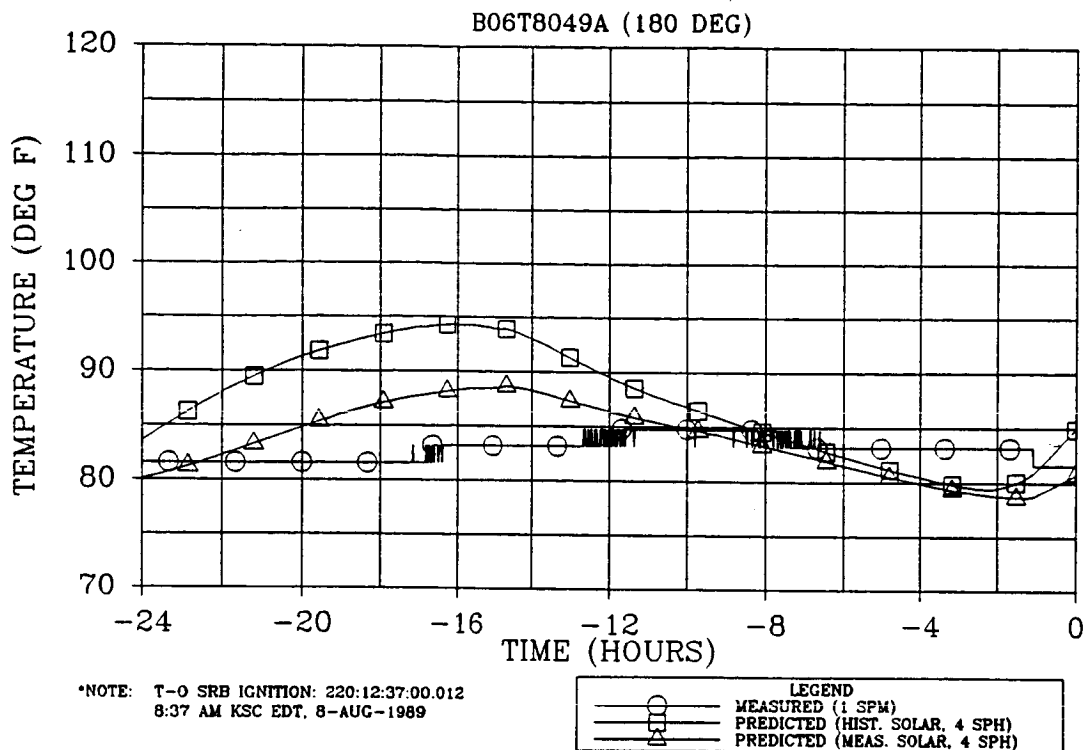


Figure 4.8-103. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Case-to-Nozzle Joint Temperature

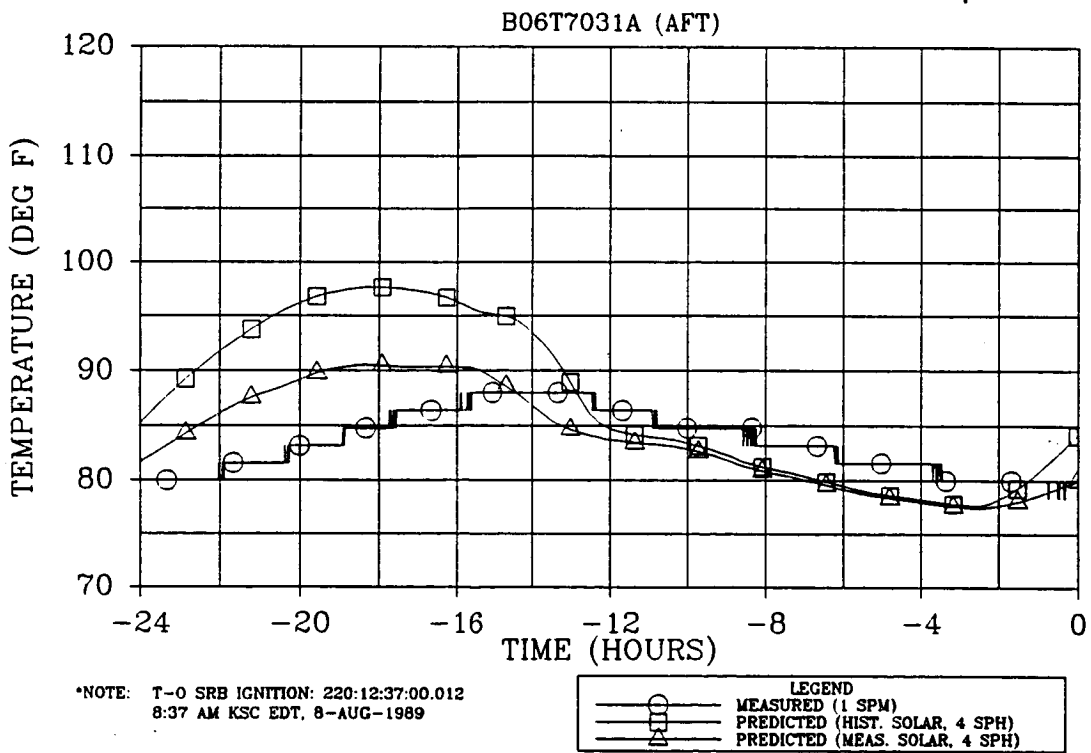


Figure 4.8-104. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction LH SRM Tunnel Bondline Temperature

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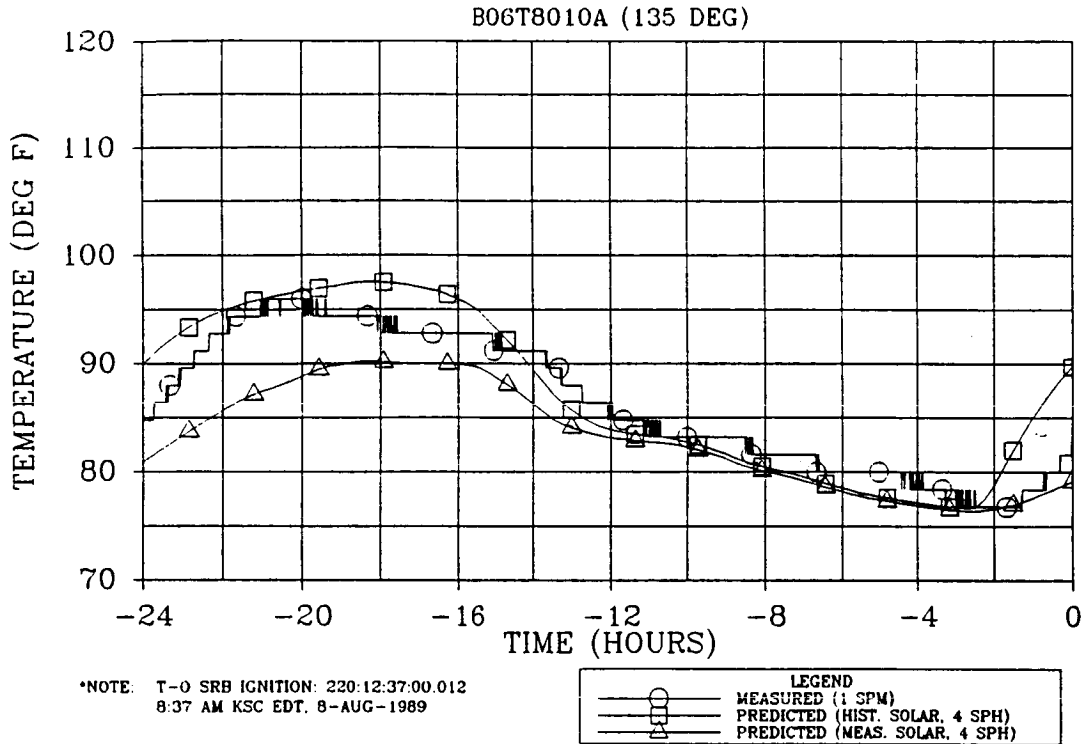


Figure 4.8-105. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Case Acreage Temperature at Station 931.5

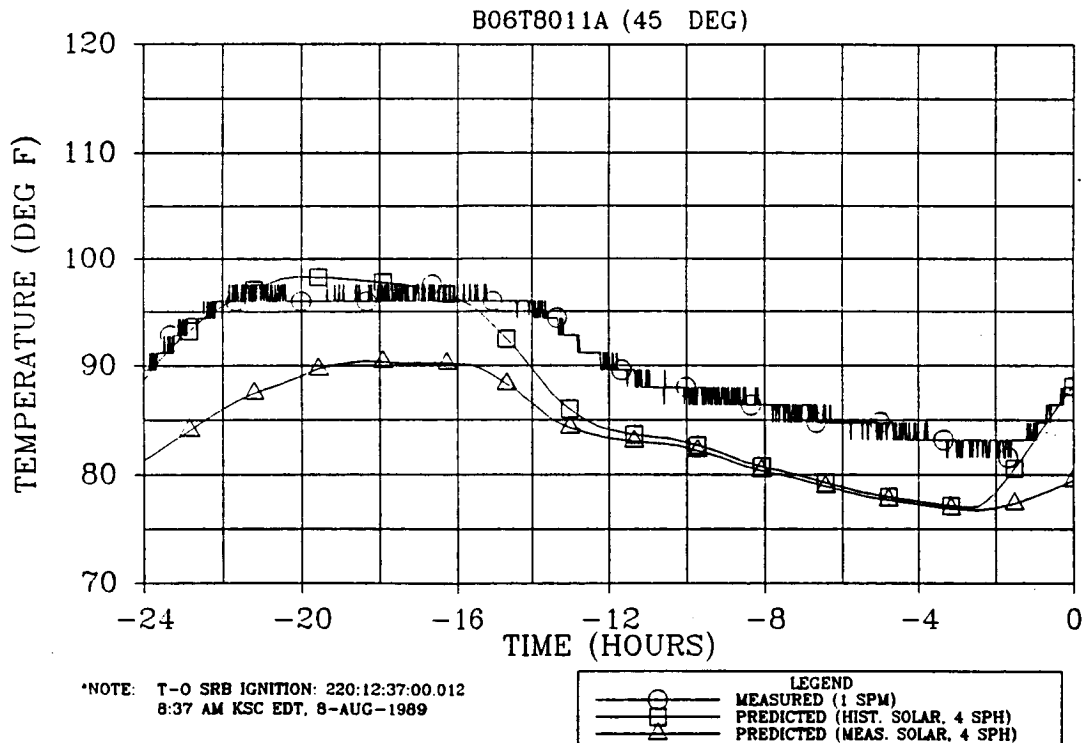


Figure 4.8-106. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Case Acreage Temperature at Station 931.5

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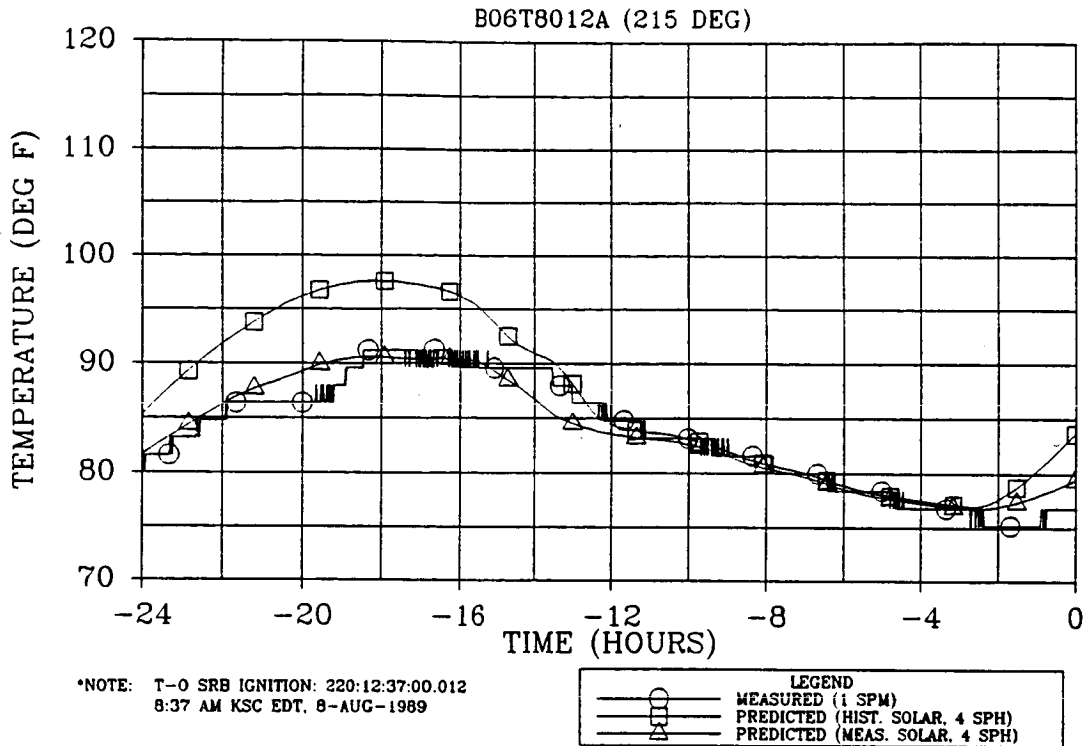


Figure 4.8-107. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Case Acreage Temperature at Station 931.5

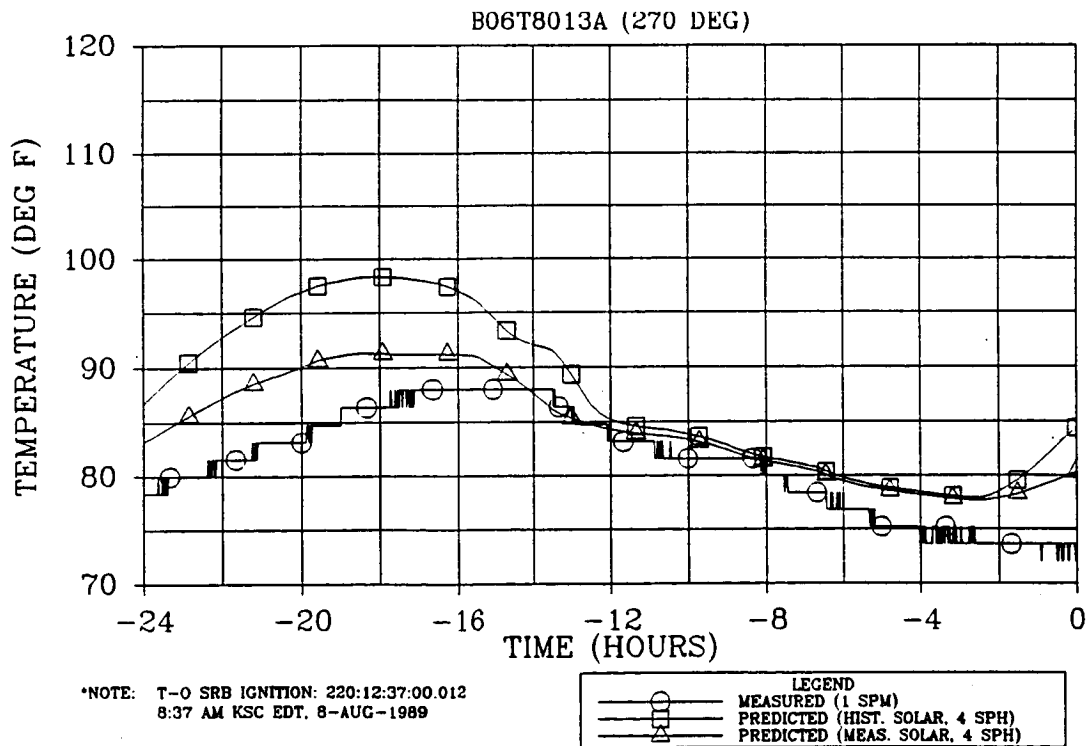


Figure 4.8-108. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Case Acreage Temperature at Station 931.5

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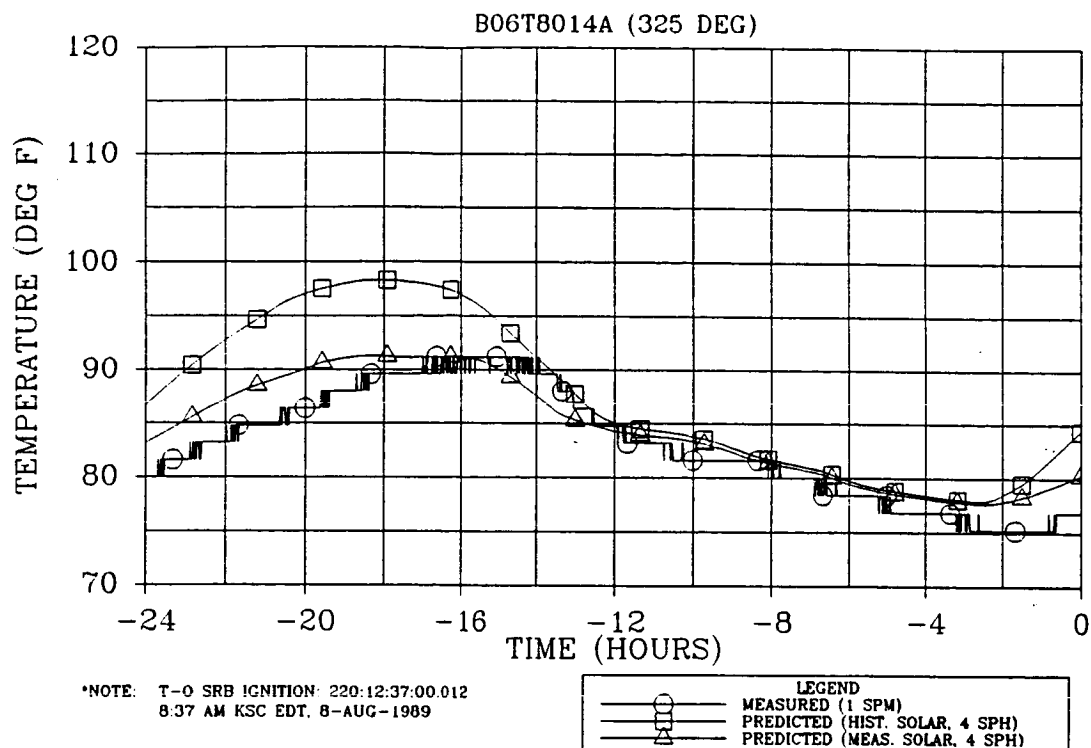


Figure 4.8-109. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Case Acreage Temperature at Station 931.5

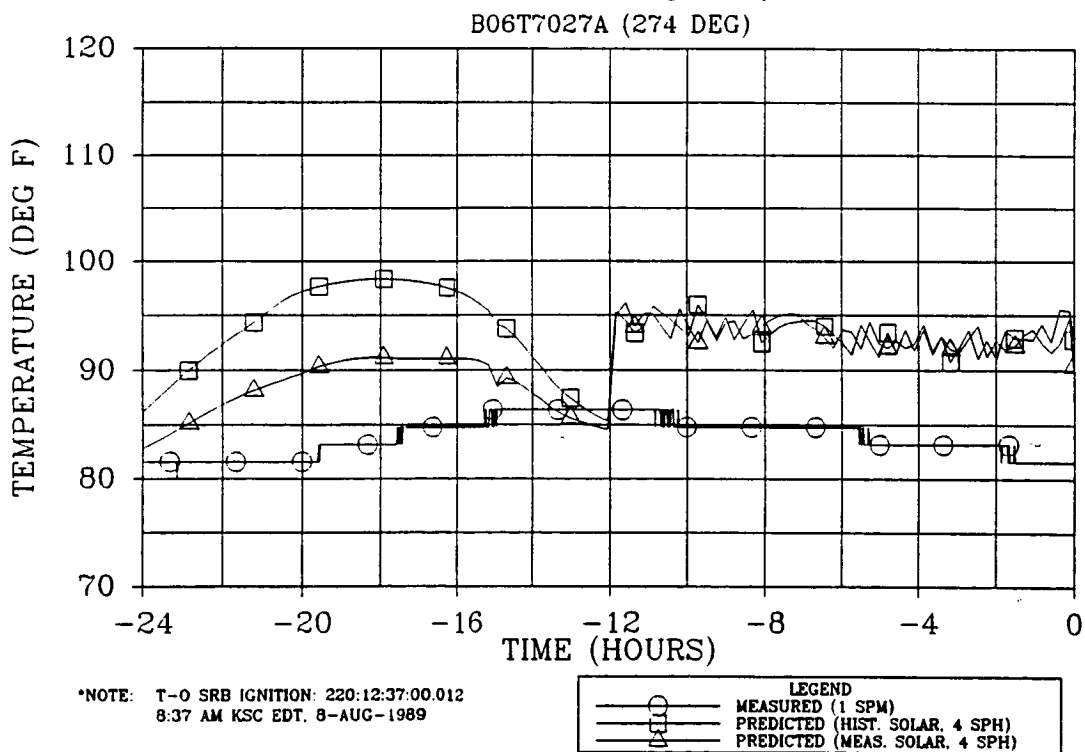


Figure 4.8-110. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for LH SRM ET Attach Region Temperature at Station 1511.0

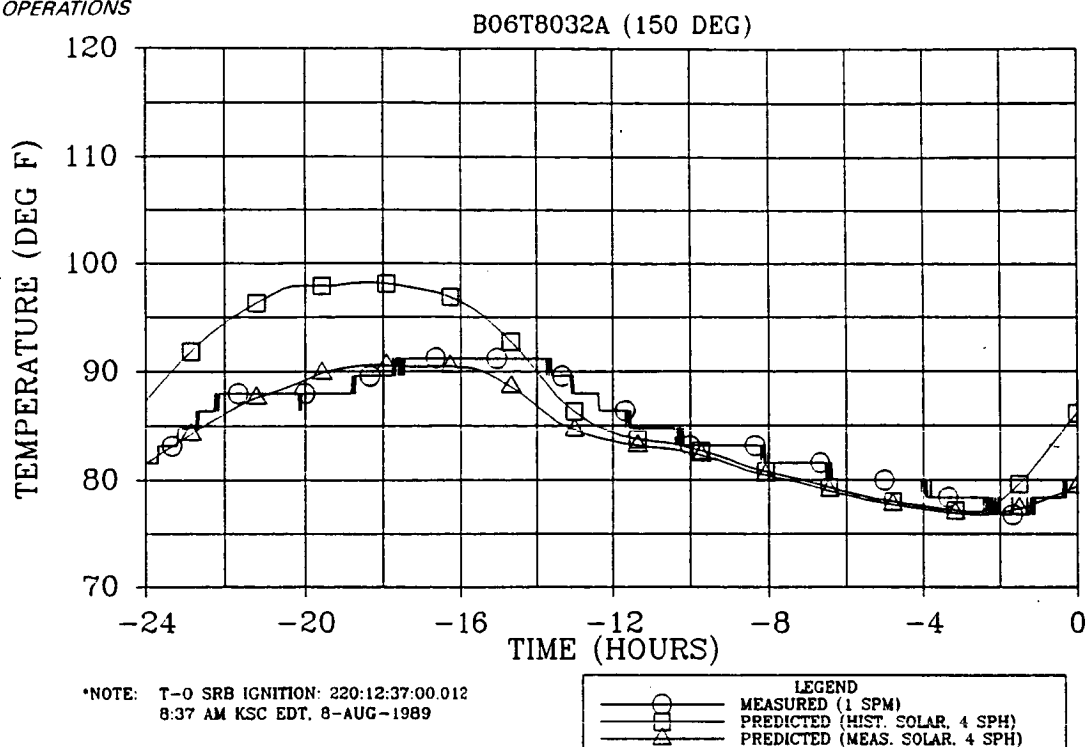


Figure 4.8-111. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Aft Factory Joint Temperature at Station 1701.9

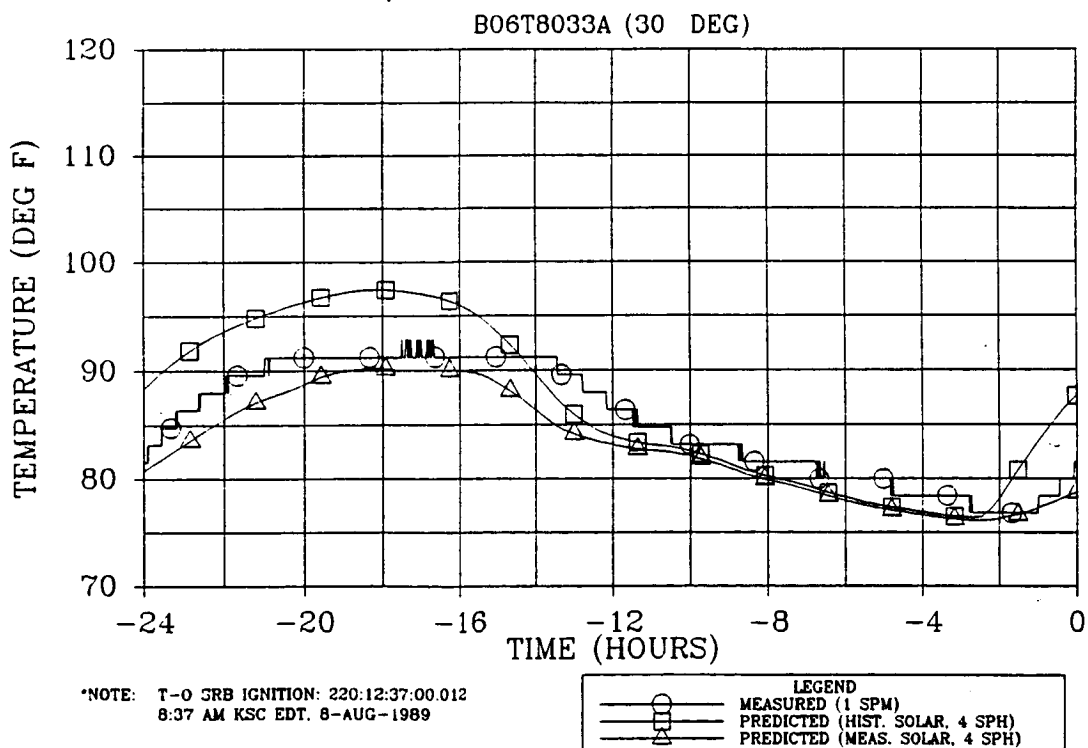
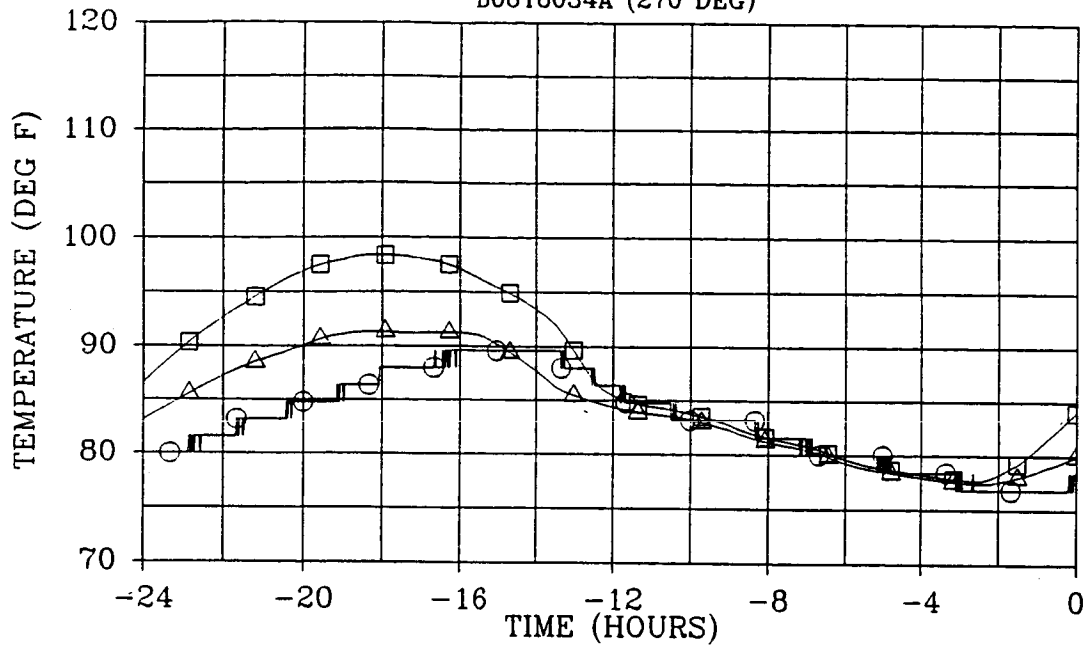


Figure 4.8-112. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Aft Factory Temperature at Station 1701.9

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B06T8034A (270 DEG)



*NOTE: T-0 SRB IGNITION: 220:12:37:00.012
8:37 AM KSC EDT, 8-AUG-1989

LEGEND
 ○ MEASURED (1 SPM)
 □ PREDICTED (HIST. SOLAR, 4 SPH)
 △ PREDICTED (NEAS. SOLAR, 4 SPH)

Figure 4.8-113. 360H005 (STS-28) GEI Data Comparison — Measured Versus Postflight Prediction for RH SRM Aft Factory Joint Temperature at Station 1701.9

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4.8.4 Conclusions and Recommendations

4.8.4.1 Postflight Hardware Inspection. Based on the quick-look external inspection, the SRM TPS performed adequately on STS-28R. No unexpected heating effects were noted. The SRM TPS design, from a thermal perspective, continues to suggest that the worst-case flight design environments of the integrated vehicle baseline configuration (IVBC-3) and SRB reentry are--for the most part--overly conservative. An exception to this is the environment in the nozzle base region during reentry when hydrazine fires and excessive nozzle flame heating are present (refer to STS-29R Final Report, TWR-17542, Volume I).

4.8.4.2 Debris. No SRM violations of NSTS debris criteria were noted. Based on the postflight hardware inspections of STS-28 and STS-30, the problem of losing TPS cork caps covering the GEI cables due to poor cork bonds appears to have been alleviated. The K5NA closeout in place of the cork caps is performing excellently and as expected. All missing TPS cork pieces (generally small) are due to nozzle severance debris and/or splashdown loads and debris.

A potential debris problem was acknowledged during STS-30R open assessment concerning the GEI labels which are covered with a thick layer of epoxy. Because of this assessment all GEI MSID labels forward of the ET attach ring were removed prior to launch. Most of the remaining labels on the aft segment of STS-28R were lost during flight, but are not considered a debris issue because they are located aft of the orbiter.

4.8.4.3 GEI Prediction. Additional model enhancement is recommended for certain motor regions in order to improve predictions. It should be noted, however, that the attainment of actual solar radiation data improved postflight prediction significantly. Submodel development effort for the areas of the ET attach ring, field joint, factory joint, systems tunnel, igniter, and nozzle regions is anticipated. These tasks would be encompassed by the global model effort. It is also recommended that all these models, including the 3-D SRM model, be made available for use at MSFC. This would allow Thiokol thermal personnel the opportunity to support launch countdowns at the HOSC with real-time PMBT, GEI, and component prediction updates. This would also allow MSFC thermal personnel the same modeling capabilities.

4.8.4.4 Aft Skirt Conditioning. It is apparent, based on the cold environment experienced by STS-28 and STS-29R, that substantial gas cooling occurs in the ducting system before the gas enters the aft skirt. It is recommended that the gas temperature be monitored as it enters the aft skirt compartment. During cold weather this would allow the use of a higher operating temperature and at the same time not violate the 115°F maximum within the compartment.

4.8.4.5 GEI Accuracy. It is recommended that the GEI data collection accuracy be increased by reducing the gage range and increasing the digital word length. The real fidelity of the KSC GSE could then be quantified and conceivably replaced if determined to be inadequate.

4.8.4.6 Local Chilling. Based on data from STS-28, STS-29R, and STS-30R, local cooling does occur. It is recommended that a method be developed to accurately quantify the chill effect.

4.8.4.7 IR Measurements. The STI data continue to be much more reliable than IR gun measurements. Comparisons with GEI are within acceptable margins for STI data, but are questionable and unpredictable for IR gun data. For future flights it is recommended that 1/2-hr STI versus GEI direct comparisons be made and documented.

4.9 DFI MEASUREMENT SYSTEM PERFORMANCE (FEWG REPORT PARAGRAPH 2.9.5)

Flight motor set 360H005 did not have any DFI installed. This section is reserved pending any future motors that incorporate DFI.

4.10 MEASUREMENT SYSTEM PERFORMANCE (FEWG REPORT PARAGRAPH 2.9.7)

4.10.1 Instrumentation Summary

Table 4.10-1 shows the location and number of instrumentation for 360H005. Note that the igniter heater sensors are classified as GEI, whereas the field joint heater sensors are listed under a separate category. The OFI consists of the three OPTs which are used to determine the SRB separation time.

Table 4.10-1. 360H005 (STS-28R) Instrumentation

<u>Parameter</u>	<u>LH</u>			<u>RH</u>			<u>Total</u>
	<u>OFI</u>	<u>GEI</u>	<u>Htr</u>	<u>OFI</u>	<u>GEI</u>	<u>Htr</u>	
Pressure		3			3		6
Temperature		54*	12		54*	12	132
							138

*Includes igniter heater sensors

4.10.2 GEI/OFI Performance

The GEI instrumentation on flight set 360H005 consisted of 108 resistance temperature device (RTD) sensors which monitor motor case temperature while the motor is on the pad. The OFI consists of three OPTs on each forward dome. One hundred percent of the GEI gages were functioning and all were within the allowable variation before launch. (All GEI are disconnected by breakaway umbilicals at SRB ignition and are not operative during flight). Tables 4.10-2 and 4.10-3 list the GEI instrumentation and include comments telling which gages consistently read differently from surrounding gages. Figures 4.8-6 and 4.8-8 through 4.8-10 show GEI/OFI locations.

The OFI consists of three OPTs on each forward dome. The results of the 75-percent calibration (performed at T-1.5 hr) verified that readings were well within the 740- to 804-psia allowable range and are listed below.

<u>360H005A (LH)</u>		<u>360H005B (RH)</u>	
<u>Gage</u>	<u>Reading</u>	<u>Gage</u>	<u>Reading</u>
B47P1300C	762.8	B47P2300C	767.8
B47P1301C	765.8	B47P2301C	765.8
B47P1302C	763.8	B47P2302C	765.8

4.10.3 Heater Sensor Performance

Evaluation of the field joint heaters and heater sensor performance was discussed previously in Section 4.8.3 of this volume. Table 4.10-4 lists the joint heater sensors; Figure 4.8-7 shows the gage locations.

Table 4.10-2. GEI List--LH SRM (360H005A)

<u>Instrument No.</u>	<u>Location (deg)</u>	<u>Station</u>	<u>Range (°F)</u>	<u>Case Location</u>	<u>Comments</u>
B06T7003A	270	534.5	± 200	Forward segment	
B06T7004A	45	694.5	± 200	Forward segment	
B06T7005A	135	694.5	± 200	Forward segment	
B06T7006A	325	694.5	± 200	Forward segment	
B06T7007A	270	694.5	± 200	Forward segment	
B06T7008A	215	694.5	± 200	Forward segment	Reads 5°F high
B06T7009A	90	778.98	± 200	Forward segment (systems tunnel)	
B06T7010A	45	931.48	± 200	Forward center segment	
B06T7011A	135	931.48	± 200	Forward center segment	
B06T7012A	325	931.48	± 200	Forward center segment	
B06T7013A	270	931.48	± 200	Forward center segment	
B06T7014A	215	931.48	± 200	Forward center segment	
B06T7015A	45	1091.48	± 200	Forward center segment	
B06T7016A	135	1091.48	± 200	Forward center segment	
B06T7017A	325	1091.48	± 200	Forward center segment	
B06T7018A	270	1091.48	± 200	Forward center segment	
B06T7019A	215	1091.48	± 200	Forward center segment	
B06T7020A	90	1258.98	± 200	Aft center segment (systems tunnel)	
B06T7021A	45	1411.48	± 200	Aft center segment	
B06T7022A	135	1411.48	± 200	Aft center segment	
B06T7023A	325	1411.48	± 200	Aft center segment	
B06T7024A	270	1411.48	± 200	Aft center segment	
B06T7025A	215	1411.48	± 200	Aft center segment	
B06T7026A	220	1511	± 200	ET attach ring	
B06T7027A	274	1511	± 200	ET attach ring	
B06T7028A	320	1511	± 200	ET attach ring	
B06T7029A	45	1535	± 200	Aft segment	
B06T7030A	135	1535	± 200	Aft segment	
B06T7031A	90	1565	± 200	Aft segment (systems tunnel)	
B06T7032A	30	1701.86	± 200	Aft segment	Reads 5°F high
B06T7033A	150	1701.86	± 200	Aft segment	
B06T7034A	270	1701.86	± 200	Aft segment	
B06T7035A	45	1751.5	± 200	Aft segment	
B06T7036A	135	1751.5	± 200	Aft segment	
B06T7037A	325	1751.5	± 200	Aft segment	
B06T7038A	270	1751.5	± 200	Aft segment	
B06T7039A	215	1751.5	± 200	Aft segment	
B06T7040A	30	1821	± 200	Aft segment	
B06T7041A	150	1821	± 200	Aft segment	
B06T7042A	270	1821	± 200	Aft segment	
B06T7043A	0	1847	± 200	Flex bearing	
B06T7044A	0	1845	± 200	Nozzle throat	
B06T7045A	120	1847	± 200	Flex bearing	
B06T7046A	120	1845	± 200	Nozzle throat	
B06T7047A	240	1847	± 200	Flex bearing	
B06T7048A	240	1845	± 200	Nozzle throat	

Table 4.10-2. GEI List--LH SRM (360H005A) (Cont)

<u>Instrument No.</u>	<u>Location (deg)</u>	<u>Station</u>	<u>Range (°F)</u>	<u>Case Location</u>	<u>Comments</u>
B06T7049A	0	1876.6	± 200	Case-to-nozzle joint	
B06T7050A	120	1876.6	± 200	Case-to-nozzle joint	
B06T7051A	240	1876.6	± 200	Case-to-nozzle joint	
B06T7052A	0	1950	± 200	Exit cone	
B06T7053A	120	1950	± 200	Exit cone	
B06T7054A	240	1950	± 200	Exit cone	
B06T7085A	184.5	486.4	± 200	Igniter	
B06T7086A	355.5	486.4	± 200	Igniter	

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Table 4.10-3. GEI List--RH SRM (360H005B)

<u>Instrument No.</u>	<u>Location (deg)</u>	<u>Station</u>	<u>Range (°F)</u>	<u>Case Location</u>	<u>Comments</u>
B06T8003A	270	534.5	±200	Forward segment	
B06T8004A	135	694.5	±200	Forward segment	
B06T8005A	45	694.5	±200	Forward segment	
B06T8006A	215	694.5	±200	Forward segment	
B06T8007A	270	694.5	±200	Forward segment	
B06T8008A	325	694.5	±200	Forward segment	
B06T8009A	90	778.98	±200	Forward segment (systems tunnel)	
B06T8010A	135	931.48	±200	Forward center segment	
B06T8011A	45	931.48	±200	Forward center segment	
B06T8012A	215	931.48	±200	Forward center segment	
B06T8013A	270	931.48	±200	Forward center segment	
B06T8014A	325	931.48	±200	Forward center segment	
B06T8015A	135	1091.48	±200	Forward center segment	
B06T8016A	45	1091.48	±200	Forward center segment	
B06T8017A	215	1091.48	±200	Forward center segment	
B06T8018A	270	1091.48	±200	Forward center segment	
B06T8019A	325	1091.48	±200	Forward center segment	
B06T8020A	90	1258.98	±200	Aft center segment (systems tunnel)	
B06T8021A	135	1411.48	±200	Aft center segment	
B06T8022A	45	1411.48	±200	Aft center segment	
B06T8023A	215	1411.48	±200	Aft center segment	
B06T8024A	270	1411.48	±200	Aft center segment	
B06T8025A	325	1411.48	±200	Aft center segment	
B06T8026A	320	1511	±200	ET attach ring	
B06T8027A	266	1511	±200	ET attach ring	
B06T8028A	220	1511	±200	ET attach ring	
B06T8029A	135	1535	±200	Aft segment	
B06T8030A	45	1535	±200	Aft segment	
B06T8031A	90	1565	±200	Aft segment (systems tunnel)	
B06T8032A	150	1701.86	±200	Aft segment	
B06T8033A	30	1701.86	±200	Aft segment	
B06T8034A	270	1701.86	±200	Aft segment	
B06T8035A	135	1701.86	±200	Aft segment	
B06T8036A	45	1751.5	±200	Aft segment	
B06T8037A	215	1751.5	±200	Aft segment	
B06T8038A	270	1751.5	±200	Aft segment	
B06T8039A	325	1751.5	±200	Aft segment	
B06T8040A	150	1821	±200	Aft segment	
B06T8041A	30	1821	±200	Aft segment	
B06T8042A	270	1821	±200	Aft segment	
B06T8043A	180	1847	±200	Flex bearing	
B06T8044A	180	1845	±200	Nozzle throat	
B06T8045A	60	1847	±200	Flex bearing	
B06T8046A	60	1845	±200	Nozzle throat	
B06T8047A	300	1847	±200	Flex bearing	
B06T8048A	300	1845	±200	Nozzle throat	

Table 4.10-3. GEI List--RH SRM (360H005B) (Cont)

<u>Instrument No.</u>	<u>Location (deg)</u>	<u>Station</u>	<u>Range (°F)</u>	<u>Case Location</u>	<u>Comments</u>
B06T8049A	180	1876.6	± 200	Case-to-nozzle joint	
B06T8050A	60	1876.6	± 200	Case-to-nozzle joint	
B06T8051A	300	1876.6	± 200	Case-to-nozzle joint	
B06T8052A	180	1950	± 200	Exit cone	
B06T8053A	60	1950	± 200	Exit cone	
B06T8054A	300	1950	± 200	Exit cone	
B06T8085A	355.5	486.4	± 200	Igniter	
B06T8086A	184.5	486.4	± 200	Igniter	

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Table 4.10-4. Field Joint Heater Temperature Sensor Lists (both motors)

Instrument No.	Location (deg)	Station	Range (°F)	Required Accuracy (%)	Digital*	Remarks	Comments
<u>LH SRM Heater Temperature Sensor List</u>							
B07T7060	15	851.5	±200	±1	1	Forward heater	
B07T7061	135	851.5	±200	±1	1	Forward heater	
B07T7062	195	851.5	±200	±1	1	Forward heater	
B07T7063	285	851.5	±200	±1	1	Forward heater	
B07T7064	15	1171.5	±200	±1	1	Center heater	
B07T7065	135	1171.5	±200	±1	1	Center heater	
B07T7066	195	1171.5	±200	±1	1	Center heater	
B07T7067	285	1171.5	±200	±1	1	Center heater	
B07T7068	15	1491.5	±200	±1	1	Aft heater	
B07T7069	135	1491.5	±200	±1	1	Aft heater	
B07T7070	195	1491.5	±200	±1	1	Aft heater	
B07T7071	285	1491.5	±200	±1	1	Aft heater	

RH SRM Heater Temperature Sensor List

B07T8060	15	851.5	±200	±1	1	Forward heater	
B07T8061	135	851.5	±200	±1	1	Forward heater	
B07T8062	195	851.5	±200	±1	1	Forward heater	
B07T8063	285	851.5	±200	±1	1	Forward heater	
B07T8064	15	1171.5	±200	±1	1	Center heater	
B07T8065	135	1171.5	±200	±1	1	Center heater	
B07T8066	195	1171.5	±200	±1	1	Center heater	
B07T8067	285	1171.5	±200	±1	1	Center heater	
B07T8068	15	1491.5	±200	±1	1	Aft heater	
B07T8069	135	1491.5	±200	±1	1	Aft heater	
B07T8070	195	1491.5	±200	±1	1	Aft heater	
B07T8071	285	1491.5	±200	±1	1	Aft heater	

*Sampling rate is given in samples per minute (SPM).

Table 4.10-5. S&A Device Arm and Safe Delta Times

SRN IGNITION S&A ROTATION - STS-26R (H47500.078 - IGNITION S&A FUNCTIONAL TEST)												
ROTATE #	GMT	CONVARD	GMT	RESPONSE	DELTA	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	RICH
1	163113.238	1	163114.344	1	1.106	1	1.106	1	1.106	1	1.106	1
	163113.478	1	163114.464	1	0.986	1	0.986	1	0.986	1	0.986	1
	163121.116	1	163121.945	1	0.827	1	0.827	1	0.827	1	0.827	1
	163121.356	1	163122.265	1	0.907	1	0.907	1	0.907	1	0.907	1
2	163221.438	1	163224.344	1	0.906	1	0.906	1	0.906	1	0.906	1
	163223.678	1	163224.665	1	0.987	1	0.987	1	0.987	1	0.987	1
	163231.198	1	163232.144	1	0.946	1	0.946	1	0.946	1	0.946	1
	163231.438	1	163232.265	1	0.827	1	0.827	1	0.827	1	0.827	1
3	163257.918	1	163258.745	1	0.827	1	0.827	1	0.827	1	0.827	1
	163258.158	1	163259.064	1	0.906	1	0.906	1	0.906	1	0.906	1
	163305.678	1	163306.544	1	0.866	1	0.866	1	0.866	1	0.866	1
	163305.918	1	163306.864	1	0.946	1	0.946	1	0.946	1	0.946	1
4	163350.399	1	163351.144	1	0.746	1	0.746	1	0.746	1	0.746	1
	163350.638	1	163351.464	1	0.826	1	0.826	1	0.826	1	0.826	1
	163358.838	1	163358.944	1	0.906	1	0.906	1	0.906	1	0.906	1
	163358.278	1	163359.265	1	0.987	1	0.987	1	0.987	1	0.987	1
5	163426.578	1	163427.344	1	0.826	1	0.826	1	0.826	1	0.826	1
	163426.798	1	163427.665	1	0.867	1	0.867	1	0.867	1	0.867	1
	163434.196	1	163434.945	1	0.747	1	0.747	1	0.747	1	0.747	1
	163434.438	1	163435.265	1	0.827	1	0.827	1	0.827	1	0.827	1
6	163502.828	1	163503.745	1	0.907	1	0.907	1	0.907	1	0.907	1
	163503.078	1	163503.864	1	0.786	1	0.786	1	0.786	1	0.786	1
	163510.398	1	163511.144	1	0.746	1	0.746	1	0.746	1	0.746	1
	163510.678	1	163511.664	1	0.986	1	0.986	1	0.986	1	0.986	1
7	163539.718	1	163540.544	1	0.826	1	0.826	1	0.826	1	0.826	1
	163539.958	1	163540.864	1	0.906	1	0.906	1	0.906	1	0.906	1
	163547.478	1	163548.344	1	0.866	1	0.866	1	0.866	1	0.866	1
	163547.718	1	163548.665	1	0.947	1	0.947	1	0.947	1	0.947	1
8	163613.078	1	163613.944	1	0.826	1	0.826	1	0.826	1	0.826	1
	163613.398	1	163614.265	1	0.867	1	0.867	1	0.867	1	0.867	1
	163620.758	1	163621.544	1	0.786	1	0.786	1	0.786	1	0.786	1
	163620.998	1	163621.864	1	0.865	1	0.865	1	0.865	1	0.865	1
9	163643.558	1	163644.344	1	0.786	1	0.786	1	0.786	1	0.786	1
	163643.798	1	163644.664	1	0.866	1	0.866	1	0.866	1	0.866	1
	163651.318	1	163652.144	1	0.826	1	0.826	1	0.826	1	0.826	1
	163651.558	1	163652.464	1	0.906	1	0.906	1	0.906	1	0.906	1
10	163712.718	1	163713.544	1	0.826	1	0.826	1	0.826	1	0.826	1
	163712.958	1	163713.864	1	0.906	1	0.906	1	0.906	1	0.906	1
	163720.438	1	163721.344	1	0.906	1	0.906	1	0.906	1	0.906	1
	163720.678	1	163721.664	1	0.786	1	0.786	1	0.786	1	0.786	1

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4.10.4 S&A Device Rotation Times

Table 4.10-5 includes the arm and safe delta times for the S&A device functional test performed prior to the STS-28R countdown. It can be seen that all values are less than the required 2.0 sec. Table 4.10-6 lists the arm and safe times during the actual launch sequence (at T-5 min). As was the case with the functional test, all values are less than 2.0 sec.

Table 4.10-6. S&A Device Activity Times For 360H005 (STS-28R)--
8 August 1989 at T-5 Min

<u>Activity</u>	<u>Device Location</u>	<u>Action Time (sec)</u>
Rotation	LH	1.044*
	RH	1.125*
Command to Arm	LH	1.044
	RH	1.125

*Data sample rate is five times per second; therefore, actual rotation times could be 0.200 sec sooner.
Command times are as indicated

4.11 RSRM HARDWARE ASSESSMENT (FEWG REPORT PARAGRAPH 2.11.2)

4.11.1 Insulation Performance

4.11.1.1 Summary. All weatherseal unbonds resulted from splashdown loads. No gas paths through the case-to-nozzle joint polysulfide adhesive or any other anomalous joint conditions were identified. The internal insulation in all six of the case field joints also performed as designed, with no anomalous conditions. There were no recordable clevis edge separations (over 0.1 in.). No evidence of hot gas penetration through any of the acreage insulation or severe erosion patterns were identified. A ply separation was identified in the internal insulation of the RH aft center segment, resulting in an IFA. See Section 4.1 of this report for a complete discussion. The ply separation did not affect motor performance. A complete insulation performance evaluation is in Volume III of this report.

4.11.1.2 External Insulation

Factory Joint Weatherseals. Two of the 14 factory joint weatherseals showed signs of aft edge unbonds. No evidence of sooting or heat effects was found under any of these unbonds indicating that they occurred at or after splashdown. The weatherseals on the remaining factory joints performed satisfactorily.

Two unbonds were identified on the aft edge of the weatherseal on the LH forward segment cylinder-to-cylinder factory joint. At 0 deg, the unbond measured 6.4 in. circumferentially and extended to the pin retainer band. Water was leaking from this unbond and rust contamination was observed on the case under the unbond. At 50 deg an unbond was observed which measured 2.0 in. circumferentially and extended to a maximum depth of 0.5 inch. No leakage or rust was observed at this unbond. Both unbonds on this factory joint failed adhesively between the Chemlok 205[®] and the case.

One unbond was observed on the aft edge of the weatherseal on the LH aft center segment factory joint. This unbond was located at 30 deg and intermittently measured 3.5 in. circumferentially; it extended to a maximum depth of 0.5 inch. This unbond also showed adhesive failure between the Chemlok 205[®] and the case.

Stiffener Stubs and Rings. The insulation over the stiffener stubs and rings was in good condition. The EPDM was well bonded to the stiffener stubs and appeared to be well bonded to the stiffener rings as evidenced by the tap test of all exposed surfaces prior to and after hydrolazing.

4.11.1.3 Case-to-Nozzle Joints. Based on the visual evaluation, both case-to-nozzle joints performed well. No gas paths through the polysulfide adhesive or any other anomalous conditions were identified. The disassembled joints showed the failure mode was 80 percent cohesive in the polysulfide, 5 percent adhesive failure to the nitrile butadiene rubber (NBR) and 15 percent adhesive failure to the fixed housing phenolic on the LH motor and 70 percent cohesive in the polysulfide, 20 percent adhesive failure to the NBR and 10 percent adhesive failure to the fixed housing phenolic on the RH motor. There were two voids identified in the polysulfide adhesive on each

case-to-nozzle joint, with the largest void measuring 1.3 in. longitudinally by 0.3 in. circumferentially. The polysulfide vent slot fill on these motors was relatively low at 41 percent and 9 percent for the LH and RH motors, respectively.

4.11.1.4 Field Joints. All of the case field joint insulation was in good condition with uniform erosion and heat effects. Good adhesive contact was evident on all field joints. Sooting observed outboard from the remaining material on the tang and clevis, due to splashdown, ranged from 0.0 to 0.40 inch. Probing of the clevis insulation bondline revealed no unbonds exceeding the 0.10 in. depth postfire engineering evaluation limit (PEEL) requirement. The maximum observed unbond was approximately 0.07 in. deep identified on the RH center field joint. Some tang edge separations were visible; however, measurements and further evaluation will be conducted in Building H-7 at the Clearfield, Utah, facility.

Intermittent crazing and cracking was noted on the radius region and just inboard of the radius region on the clevis insulation of the RH aft segment. Evaluation showed that there was no measurable depth to the crazing and cracking and the condition had no adverse effect on the performance of the joint. No other crazing and cracking was observed on any other joint. Further evaluation will be conducted at the Clearfield facility.

All NBR inhibitors and stress relief flaps performed as expected with no abnormal erosion or tears. A patch, which had been secondarily bonded to the flap of the LH forward center segment during a repair of a defect at motor fabrication, was missing. It was apparent that the patch had been lost during splashdown since no heat effects were found on the flap surface where the patch had been bonded.

4.11.1.5 Igniter-to-Case Joints. The igniter chamber insulation, as well as the igniter-to-case joint insulation for both igniter joints, showed normal erosion. One blowhole through the putty of the LH igniter-to-case joint was present. The blowhole measured 0.90 in. circumferentially and 1.4 in. longitudinally. No soot was visible on the putty except directly at the

blowhole. No blowholes were identified in the igniter-to-adapter joint on this motor.

One blowhole was observed through the putty of the RH igniter-to-case joint at 270 deg. The starting jet blowhole measured 0.25 in. circumferentially and the through blowhole measured 2.0 in. circumferentially at its widest location. Soot was evident on the igniter adapter extending approximately 3.5 in. on each side of the blowhole. Two terminated blowholes were observed at the igniter adapter to igniter chamber joint on the RH motor at 124 and 233 deg.

4.11.1.6 Internal Acreage Insulation. Small impact gouges were identified on the insulation surface of several segments. No erosion or heat effects were observed at the edges of these gouges, indicating that the damage occurred during splashdown. A larger separation was identified on the RH aft center segment at approximately 296 deg. This separation was in a straight line located 42 in. from the tang end, measuring 11.5 in. circumferentially and extending 1.1 in. longitudinally at the center at the separation and 0.5 in. longitudinally at the ends of the separation. Again, no heat effects were found in the separation which suggests impact damage. Further evaluation will be conducted at the Clearfield facility.

4.11.2 Case Component Performance

4.11.2.1 Summary. Evaluation of the steel case indicated that the hardware performed as expected during flight. Based on missing Instafoam®, the cavity collapse load centerlines for the RH and LH motors were estimated to be at 105 and 350 deg, respectively. No new damage was noted on the LH stiffener stubs or ET attach stubs. Complete case evaluation results are in Volume II of this report.

4.11.2.2 Stiffener Stubs, Stiffener Rings, and ET Attach Stubs. The cavity collapse load was centered at approximately 350 deg for the LH motor. No new damage was noted on the LH stiffener stubs or ET attach stubs. The seven pre-existing outer ligament cracks were unchanged. The cavity collapse load was centered at approximately 105 deg for the RH motor. All three stiffener ring sections were damaged on the 90-deg. Eight ring-to-stub bolts were

sheared off from 92 deg through 106 deg from each section. Each ring section had cracks through the bolt holes at 108 deg, with the forward ring having the worst damage. No cracks were noted in the case stiffener or ET attach stubs.

4.11.2.3 Field Joints. The case field joint surface conditions were as expected. Fretting was found on all field joints, with the RH center field joint being the worst (deepest pit was 0.011 inch. Fretting was heavy in the area of from 260 deg through 0 to 45 deg). Figure 4.11-1 provides a subjective summary of the fretting.

Debonded paint was observed on the RH aft field joint outer clevis leg under the pin retainer band. Medium to heavy corrosion was observed over most of the circumference and in some pinholes.

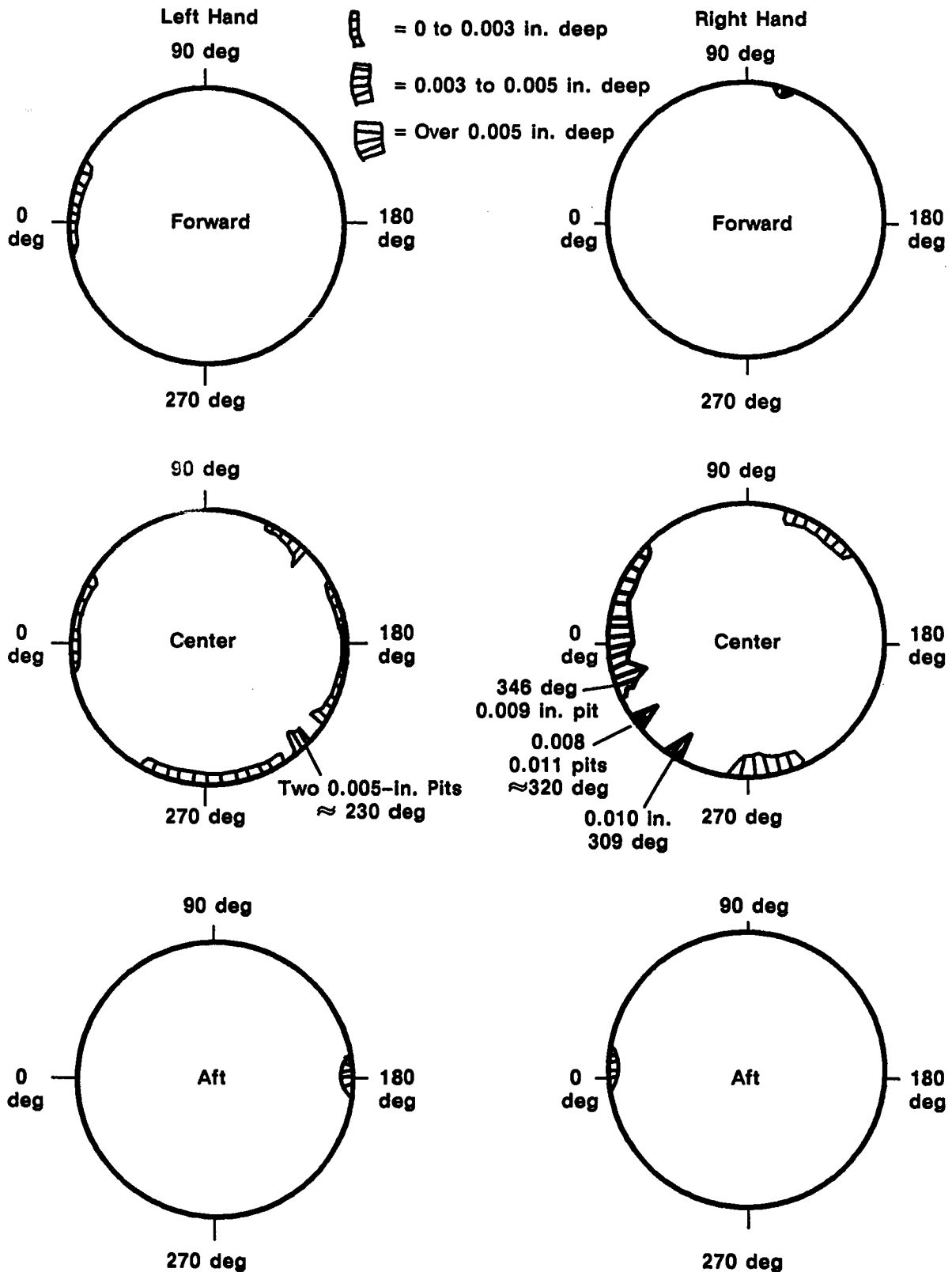
4.11.2.4 Case-to-Nozzle Joint. The case-to-nozzle joint of each motor was in excellent condition. There were no signs of metal damage to any of the sealing surfaces or boltholes or signs of heat-affected metal, corrosion, or damaged bolts.

4.11.2.5 Igniter-to-Forward Dome. The igniter-to-forward dome joint on both motors was in excellent condition. There were no signs of metal damage to any sealing surfaces or boltholes or signs of heat-affected metal, corrosion, or damaged bolts.

4.11.2.6 Forward Cylinder-to-Cylinder Factory Joint. A weatherseal unbond was identified on the forward cylinder-to-cylinder factory joint. Sea water was observed dripping from the joint. Since corrosion was present on the outer clevis leg under the unbond, grease was injected in the area to retard corrosion. The segment will be expedited through the Clearfield facility to prepare for refurbishment.

4.11.3 Seals Performance

4.11.3.1 Summary. Evaluation of the field and factory joints indicated that the internal seals performed as expected during flight. All internal seals clearly appeared to have performed well with no hot gas leakage evident. A complete evaluation is in Volume IV of this report.



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Figure 4.11-1. Motor Set 360H005 Joint Fretting Summary

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4.11.3.2 External Factory and Field Joint. There was no evidence of combustion product leakage from any joint.

4.11.3.3 Exit Cone Field Joint. All exit cone field joint components on both motors were in good condition. The O-rings were free from erosion, heat effect or any other damage and the sealing surfaces and O-ring glands were devoid of soot debris, or damage. The grease condition was nominal. No room-temperature vulcanized (RTV) material pressure paths or soot past the RTV were observed. Light, intermittent oxidation was observed on the forward face of the aft exit cones between the O-ring grooves. All other metal surfaces were in good condition. A small deposit of grey powder was found in the polysulfide material between the primary and secondary O-rings at approximately 270 deg on the LH aft exit cone. The powder was found to be silicon dioxide (SiO_2) which is used as a filler in the adhesive and in the glass-cloth phenolic (GCP). An investigation is being conducted to determine how the SiO_2 got there.

4.11.3.4 Case Field Joint. Inspection of the field joint seals revealed no anomalous conditions. All motor pressure was contained by the insulation J-joint. No corrosion or damage was found on any of the O-ring sealing surfaces. The V-2 filler was also found to be in excellent condition. None of the vent ports were obstructed by the V-2 filler. The grease application was nominal. Typical corrosion was noted on unpainted surfaces of the joints outside of the sealing areas.

4.11.3.5 OPT Special Bolt and Special Bolt Plug Seals. There was no evidence of gas leakage past the primary seals on any of the OPTs. The LH and RH primary seals saw pressure. Soot deposits were observed on the tips of the OPT threads and up to the primary seals. All of the seals performed nominally.

Special bolt primary seals were in excellent condition and performed as expected. Special bolt plug seals were also in excellent condition. All LH and RH igniter special bolts experienced typical light soot up to the primary O-ring and on the ends of the special bolts.

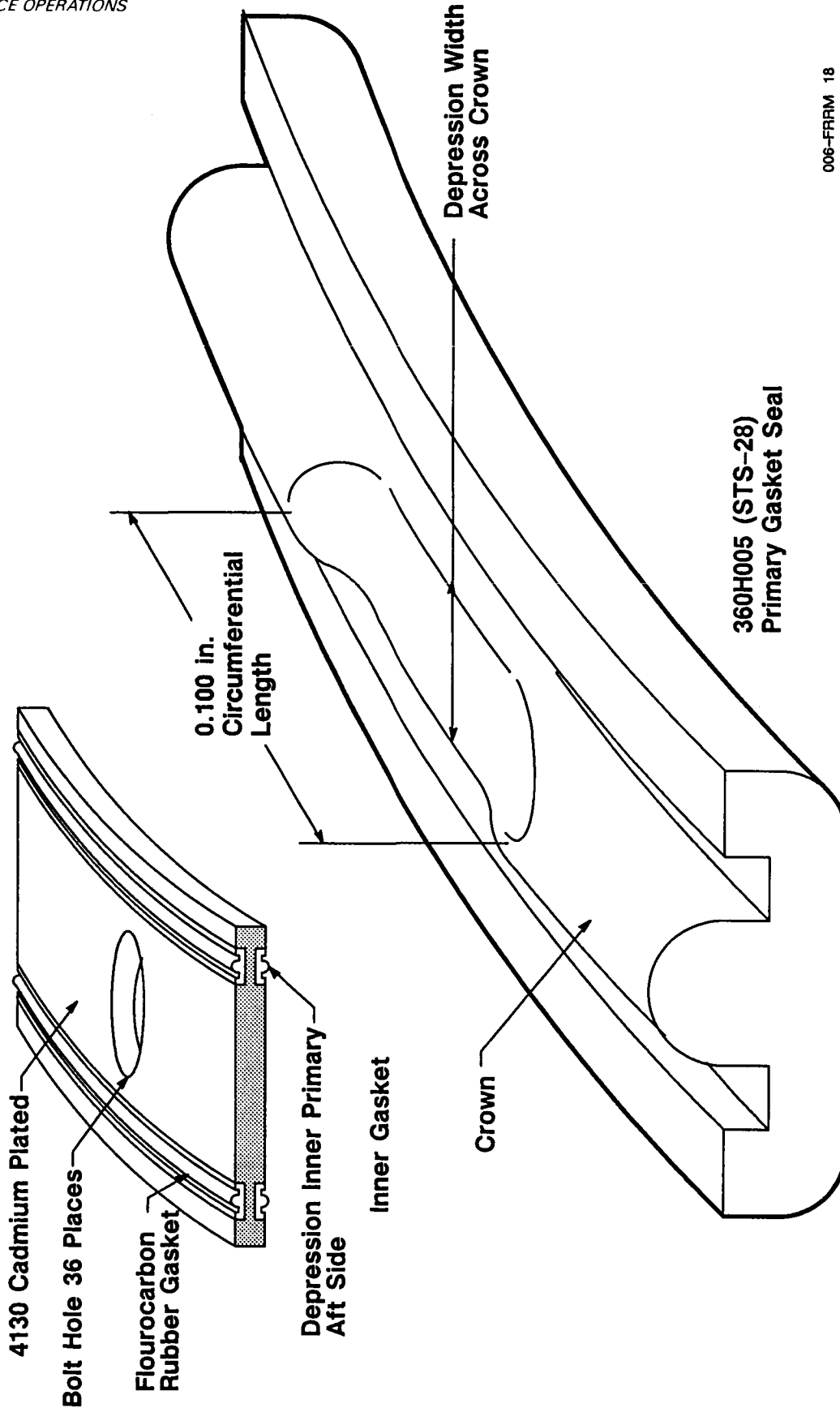
4.11.3.6 Ignition System Joint. The seals of the S&A device, igniter outer, and igniter inner gasket seals revealed no erosion or heat effect. No soot extended past the S&A device primary gasket seals.

One blowhole was observed through the putty of the LH igniter-to-case joint at 105 deg. No soot was visible on the putty except directly at the blowhole. Soot reached the primary seal from 130 to 140 deg. Intermittent corrosion was visible on the inboard edge of the LH igniter outer gasket. No blowholes were identified in the igniter chamber-to-adapter joint on the LH motor.

One blowhole was observed through the putty of the RH igniter-to-case joint at 270 deg. Soot was evident on the retainer edge around the full circumference. Light corrosion was also noted on the inboard edge of the gasket. Soot reached the aft outer primary seal of the RH igniter inner gasket at the blowhole location of 270 deg. Medium corrosion was found on the aft outboard edge of the inner gasket at 270 deg. No blowholes were identified in the igniter chamber-to-adapter joint on the RH motor.

A subsurface void was located at 220 deg on the aft face of the inner primary seal of the RH igniter inner gasket, as evidenced by an impression in the seal crown (see Figure 4.11-2). Approximate dimensions of the impression were 0.10 in. long by 0.025 in. wide. This void was made into a PR and elevated to an IFA. A concern exists that a leak test may not be sufficient to detect an indentation in flight set 360L006. The predicted joint gaps are 3.8 mil at the outer gaskets and 3.0 mil at the inner gaskets. An indentation, if present, may not dynamically track the gap opening on pressurization. Several corrective actions have been taken to screen out anomalous gaskets, as listed below.

- a. Detailed visual inspection of all gaskets in inventory for surface voids.
- b. Thorough inspection of all gaskets prior to installation.
- c. Compression test in plexiglass mold (a tool used on all gaskets for 360L008 and subsequent). A depression is easily detectable after removal of the gasket.



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Figure 4.11-2. Disassembly Evaluation of In-Flight Anomaly STS-28-M-1

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All 360L006 outer gaskets were reinspected. No anomalies were found and the 360L06 gaskets have successfully passed the reuse inspection criteria in accordance with Thiokol Standard STW7-2790.

The LH and RH igniter inner joint Stat-O-Seals[®] were in good condition with typical disassembly damage.

4.11.3.7 Case-to-Nozzle Joint. The overall joint condition was excellent on both motors. Motor pressure was halted at the polysulfide adhesive, leaving the fluorocarbon O-rings untouched. No obvious disassembly damage was noted on the wiper O-rings. The LH and RH case-to-nozzle joint Stat-O-Seals[®] were in good condition. One Stat-O-Seal[®] on the RH motor was damaged from detorque effects. Further evaluation will be performed at Thiokol Corporation, Brigham City, Utah.

4.11.3.8 Vent Port Plugs. The case field joint and case-to-nozzle joint vent port plug and seals on each motor were in excellent condition. Five out of eight vent port plugs showed typical primary O-ring extrusion damage caused by assembly. The vent port plug O-rings showed no evidence of heat effect. The fluorocarbon O-rings, glands, and metal surfaces of the plugs were free of soot, debris, and corrosion.

The case-to-nozzle joint vent port plugs had some intermittent medium corrosion on the hexagonal head of the plugs. Light corrosion was observed on the spot face of most of the ports.

4.11.3.9 Leak Check Port Plugs. The leak check port plugs and seals on the LH and RH motors in the case field joints, case-to-nozzle joints, aft exit cone joints, and the ignition system joints were in good condition. None of the leak check port plug O-rings showed any evidence of heat effect. The fluorocarbon O-rings, glands, and metal surfaces of the plugs were free of soot, debris, and corrosion.

4.11.4 Nozzle Performance

4.11.4.1 Summary. Postflight evaluation indicated both nozzles performed as expected during flight, with typical smooth and uniform erosion profiles. A complete evaluation is in Volume V of this report.

4.11.4.2 360H005A (LH) Nozzle

Aft Exit Cone. The 360H005A aft exit cone was severed by the LSC during parachute descent. The radial cut through the GCP appeared nominal, with no anomalies observed. The entire CCP liner was missing and portions of the GCP insulator were torn and delaminated. These are typical postflight observations, and occur during exit cone severance and at splashdown. The exposed GCP plies showed no signs of heat effect. A void in exposed EA946 adhesive was found at approximately 80 deg and measured 3 in. axially by 1 in. circumferentially. There was no metal exposed at this location.

The 45-deg actuator bracket showed only minor paint scrapes and chips due to actuator removal. The primer remained intact.

A small pinhole, approximately 0.010 in. diameter, was found in the polysulfide at 268 deg. This was 0.10 in. inboard of the aft exit cone shell. A small fiber, believed to be GCP, was embedded in the pinhole. A foreign residue was also found on the surface of the polysulfide from 265 to 271 deg. A sample of this residue has been taken and is undergoing analysis. There were no separations observed between the polysulfide and the aft exit cone shell. Postflight measurements of the polysulfide groove radial width showed that the GCP insulator did not pull away from the aluminum shell during cooldown. The average postflight radial width of the polysulfide groove was 0.19 inch. The polysulfide shrank axially aft up to 0.08 inch. Separations within the polysulfide measuring 0.10 in. radially were observed at 30 and 60 deg.

Separations within the GCP measuring 0.020 in. radially were noted on the outside diameter (OD) of the primary O-ring groove from 135 to 150 deg.

Forward Exit Cone Assembly. The forward 12 in. of the STS-28 LH forward exit cone CCP liner was intact and showed smooth erosion. The remaining liner was missing, except for a portion on the aft 3 to 7 in. from 180 to 210 deg. This small piece exhibited the typical dimpled erosion measuring approximately 0.1 in. deep radially.

There were no bondline separations on the aft end of the forward exit cone.

The snubbers impacted against the aft end ring resulting in paint scratches from 122 deg through 0 to 50 deg.

Throat Assembly. Erosion of the 360H005A throat and throat inlet rings was smooth and uniform. Popped-up charred CCP material was observed intermittently around the circumference on the forward ends of both rings. These are typical postburn occurrences. Throat diameter measurements will be taken at the Clearfield facilities during internal joint disassembly operations.

Nose Inlet Assembly. The 360H005A forward nose (-503) and aft inlet (-504) rings showed smooth erosion with no pockets or wash areas observed. One postburn wedgeout was found on the forward 1.1 in. of the -504 ring at 40 deg and measured 13.5 in. circumferentially by 0.45 in. radially. Popped-up charred CCP was also noted on the forward 1.2 in. at 15 deg. Slag deposits were noted on the -503 ring. Impact marks were noted at 0, 185, and 245 deg. The mark at 245 deg was covered with slag. Sectioning of this area is required to determine time of occurrence.

The nose cap exhibited typical minor wash areas on the forward 24 in. (0.15 in. maximum radial depth). The remainder of the nose cap showed smooth erosion. Postburn wedgeouts and popped-up CCP were observed on the aft 2 to 3 in. intermittently around the circumference.

Cowl Ring. The 360H005A cowl ring showed the typical ridged erosion pattern seen on previous postburn RSRM cowl rings. Postburn wedgeouts and popped-up CCP were observed on the aft 3 to 4 in. intermittently around the circumference. All cowl vent holes were plugged with soot and slag, except holes at 80, 90, 130, 180, 190, 200, 290, and 310 deg; these remained partially opened.

Outer Boot Ring. The 360H005A outer boot ring (OBR) showed smooth erosion with only intermittent minor wash areas extending from the cowl to the forward 1 in. of the OBR. Postburn, popped-up charred CCP was found

intermittently on the forward 2 inches. The OBR aft end showed typical delaminations along the charred CCP plies. The aft tip adjacent to the flex boot was fractured and wedged out intermittently around the circumference. The cowl/OBR bondline remained intact.

Fixed Housing Assembly. The 360H005A fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing showed typical postburn wedgeouts of charred CCP intermittently around the circumference. The maximum radial depth of the wedgeouts was 0.5 inch. Separations were observed on the aft end of the fixed housing between the metal and EA913 NA adhesive at 227 deg, between the adhesive and GCP at 235 deg, and within the adhesive at 110 and 230 deg. All separation measured 0.005 in. axially.

The fixed housing aft flange showed no damage to the metal surfaces, boltholes, or O-ring grooves. No corrosion of the flange surface was observed, except for minor surface rust on the alignment pin. A residue of white Teflon[®] tape adhesive was found on the steel flange next to the EA913 NA bondline.

Aft Exit Cone Field Joint. The RTV was below the joint char line 360 deg circumferentially and reached the primary O-ring from 140 to 150 deg, 180 to 190 deg, and 220 to 0 deg. The primary O-ring did not see pressure. Light aluminum oxide corrosion was observed on the aft exit cone forward end between the primary and secondary O-ring grooves intermittently around the circumference, but no pitting was observed. Minor rust was also noted on the aft end or the forward exit cone flange adjacent to the EA946 bondline.

4.11.4.3 360H005B (RH) Nozzle

Aft Exit Cone. The 360H005B aft exit cone was severed by the LSC during parachute descent. The radial cut through the GCP appeared nominal, with no anomalies observed. All of the CCP liner was missing and portions of the GCP insulator were torn and delaminated due to splashdown and exit cone severance. The exposed GCP plies showed no signs of heat effect. Missing GCP plies on the aft 6 in. of the exit cone stub exposed six small air voids in the EA946 bondline. The maximum size of the voids was approximately 4 in. axially by 2 in. circumferentially. These voids have been observed during

previous postflight examinations of exit cones and are inherent to the aft exit cone bonding process.

The 45- and 135-deg actuator brackets showed minor paint scratches resulting from actuator removal. There was no metal damage or loose bolts observed.

There were no separations observed between the polysulfide and the aft exit cone shell. Postflight measurements of the polysulfide groove radial width showed that the GCP insulator did not pull away from the aluminum shell during cooldown. The average postflight radial width of the polysulfide groove was 0.18 inch. The polysulfide appeared to have shrunk axially aft up to 0.08 inch. No loose layers of polysulfide were observed in the groove.

Forward Exit Cone Assembly. The 360H005B forward exit cone CCP liner was missing over the center 15 in. of the cone due to splashdown and DOP insertion. Postburn wedgeouts of charred CCP were observed on the forward 0.8 in. of the intact CCP liner at 0 and 340 deg. These wedgeouts circumferentially measured 11 and 12 in. long, respectively, and approximately 0.7 in. deep radially. Typical dimpled erosion was observed on the intact liner aft 10 in. and measured approximately 0.1 in. deep radially.

Bondline separation on the aft end were noted between the EA946 adhesive and steel housing intermittently around the circumference. The maximum radial width of the separations was 0.02 inch. These are typical observations of postburn bondline separations.

Thrust Assembly. Erosion of the 360H005B throat and throat inlet rings was smooth and uniform, with no wedgeouts observed. Popped-up, charred CCP material was observed intermittently around the circumference on the forward 1.3 in. of throat ring. Intermittent postburn impact marks were noted on the throat ring. Throat diameter measurements will be taken at the Clearfield facilities during internal joint disassembly operations.

Nose Inlet Assembly. The 360H005B forward nose (-503) and aft inlet (-504) rings showed smooth erosion, with no pockets or major wash areas, wedgeouts,

or popped-up material observed. Intermittent small wash areas (maximum radial depth of 0.10 in.) were observed on the -503 forward nose ring.

The nose cap exhibited typical minor wash areas on the forward 12 in. (0.15 in. maximum radial depth). Postburn wedgeouts and popped-up CCP were observed on the aft 2 to 3 in. intermittently around the circumference.

Cowl Ring. The 360H005B cowl ring showed the typical erratic erosion seen on previous postburn RSRM cowl rings. Wedgeouts and popped-up, charred CCP liner were observed intermittently around the circumference on the aft 2 in. of ring. Cowl vent holes were plugged with soot and slag, except at 50, 80, and 110 deg. The three unplugged cowl vent holes were located at wedgeout locations.

Outer Boot Ring. The 360H005B OBR showed smooth erosion. One postburn wedgeout of charred CCP material was observed on the forward 1.5 in. of OBR at 172 deg. The wedgeout measured 3.8 in. circumferentially. Delaminations of charred CCP along the 35-deg plies were observed on the flow surface. Typical delaminations into charred CCP were also found on the aft tip. The aft tip adjacent to the flex boot was fractured and wedged out intermittently around the circumference. The cowl/OBR bondline remained intact.

Fixed Housing Assembly. The 360H005B fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing showed typical postburn wedgeouts of charred CCP intermittently around the circumference. The maximum radial depth of the wedgeouts was 0.5 inch. There were no bondline separations observed on the aft end of the fixed housing. The fixed housing alignment pin showed no damage.

The fixed housing aft flange showed no damage to the metal surfaces, bolt holes, or O-ring grooves. No corrosion of the flange surface was observed, other than on the 91.8 deg alignment pin.

Aft Exit Cone Field Joint. The RTV was below the joint char line 360 deg circumferentially and reached the primary O-ring over the majority of the circumference. There were no blow paths in the joint, and the primary O-ring did not see pressure. Light aluminum oxide corrosion was observed on the aft

exit cone forward end between the primary and secondary O-ring grooves intermittently around the circumference. Heavier corrosion was observed on the forward OD corner of the aft exit cone shell intermittently around the circumference. Pitting was observed at these locations, but it could not be determined if the pitting resulted from this or previous flights. Light rust was also observed on the forward exit cone aft end between the O-ring footprints, intermittently around the circumference.

Minor displaced metal was observed on the forward exit cone aft end 91.8 deg alignment pinhole due to disassembly contact with the alignment pin. The displaced metal measured approximately 0.01 in. axially by 0.01 in. circumferentially by 0.28 in. radially.

APPLICABLE DOCUMENTS

The latest revisions of the following documents are applicable to the extent specified herein.

<u>Document No.</u>	<u>Title</u>
CPW1-3600A	Prime Equipment Contract End Item Detail Specification (including Addendum G)
MSFC-RPR-1577	Shuttle Prime Contractors FEWG Report
TWR-10211-90	Mass Properties Quarterly Status Report
TWR-15723C	Design and Verification (D&V) Plan
TWR-16340	Nondestructive Radiographic Criteria for the Space Shuttle Solid Rocket Motor Nozzle Phenolic Component
TWR-16961	External Insulation Structural Analysis
TWR-17342	Mass Properties History Log Space Shuttle 360H005-LH
TWR-17343	Mass Properties History Log Space Shuttle 360H005-RH
TWR-17542, Volume I	STS-29R Final Report
TWR-19073	Engineering Requirements Document for RSRM Fifth Flight
TWR-19345	Thermal Analysis of the Fifth Flight RSRM Aft Segment Transportation From Thiokol Corporation Space Operations to Kennedy Space Center
TWR-19678	Redesigned Solid Rocket Motor Flight Readiness Review--Level III

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